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R&M DATA ANALYSIS OF THE UH-1/AH-1 TAIL ROTOR SYSTEM

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Bell Helicopter Company

Prepared for:

Army Air Mobility Research and Development Laboratory

April 1974

EUSTIS DIRECTORATE POSITION STATEMENT

The UH-1 and AH-1 series helicopter tail rotor system reliability and maintainability (R&M) assessment presented in this report is considered to be technically sound and complete. This report is one of a series dealing with helicopter subsystems and component R&M assessments, and is considered to be directly usable in developing new system design requirements and evaluation of proposed tail rotor concepts. The report's assessment of operational effects (combat damage, foreign object damage, tree strikes, etc.) provides an excellent insight into the severe conditions confronting tail rotor systems in Army helicopter operations.

The reader's attention is drawn to Appendix VI, which describes a technique that provides a means of rapidly predicting Mean-Time-Between-Failures (MTBF) and Mean-Time-Between-Removals (MTBR) early in the life cycle (300 to 400 flight hours) for components initially installed on a fleet of helicopters. Basic input data for this prediction technique are readily available in the Major-Item-Removal-Frequency (MIRF) reports which are developed under the Army Aviation Systems Command's Reliability and Maintainability Management Improvement Techniques program of the Product Assurance Directorate. Allowance can also be made for adjusting fleet MTBR calculations for off-aircraft repair. This easy-to-apply approach provides a much more accurate basis for estimating spare component requirements or life-cycle costs than is obtained by calculating MTBF as the reciprocal of failure rate for a particular time period.

The technical monitor for this contract was Royace H. Prather of the Military Operations Technology Division of this directorate.

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This report provides reliability, maintainability, and cost analysis of historical data reported on the UH-1/AH-1 tail rotor subsystems.

The objectives of this analysis are to develop benchmark maintenance and logistic support data for the design of future helicopter anti-torque systems and to put into better perspective the cost of tail-rotor-system-associated mishaps.

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For this report, the tail rotor systems were each divided into three dynamic subsystems: the tail rotor hub and blade assembly, the tail rotor drive, and the tail rotor control. Most of the analyses were conducted at the component level. The results where appropriate were combined to determine values for the subsystems and the tail rotor systems. Special techniques used to analyze some of the data are developed.

The MTBF values obtained from Navy 3-M data on UH-1D and AH-1G components were considerably lower than those obtained from the UH-1/AH-1 Maintainability and Reliability (M&R) Program data. The unscheduled maintenance rate determined from the M&R Program data was about 34 percent higher for the AH-1G and 19 percent higher for the UH-1C than it was for the UH-1D/H. This was due to a high rate of damage to the UH-1C blades from armament debris and a higher frequency of 90^{o} gearbox failure on the AH-1G.

The MTBM for the UH-1C is much lower than that which was determined for the other aircraft because of the more frequent, 50-hour hub maintenance specified for the UH-1C.

The average maintenance task time from the analysis of monitored data is less than 20 percent of the average obtained from the analysis of the 3-M data. This difference partially results from maintenance personnel accounting for their work period by charging their time, both active and nonactive, to the maintenance tasks performed.

The maintenance man-hours per flight hour (MMH/FH) were computed for the UH-1D and AH-1G aircraft. The UH-1D system required almost 40 percent more MMH/FH than the AH-1G. The reason appears to be the large amount of maintenance performed at the intermediate level.

Mishap costs increased the basic support cost for the utility helicopters (UH-1D/H) by 58 percent and the attack helicopters (UH-1C/AH-1G) by 128 percent. The basic life-cycle support cost in dollars per flight hour for the two types was reasonably close.

The MTR and MTBR values determined from the overhaul data are considerably larger than the values obtained from the RAMMIT reports. This is to be expected since many of the removals in the RAMMIT data are for nonfailure and the assemblies are subsequently reinstalled on the same or other aircraft. The overhaul data, however, includes only those removals where the assembly is forwarded to an overhaul facility.

PREFACE

This report provides reliability, maintainability, and cost analysis of historical data reported on the UH-1/AH-1 tail rotor subsystems. This analysis was conducted under Contract DAAJ02-72-C-0028, Task 1F162205A11901, for the Eustis Directorate, U. S. Army Air Mobility Research and Development Laboratory (USAAMRDL), Fort Eustis, Virginia.

USAAMRDL technical direction was provided by Mr. Royace Prather of the Reliability and Subsystems Technical Area, Military Operations Technology Division.

The principal analyst for Bell Helicopter Company was Mr. George E. Knudsen, assisted by Mrs. P. Carr and Mr. O. L. Hensley, all of M&R Analysis. Program management was provided by Mr. J. VanWyckhouse (deceased) and Mr. L. Erb, Manager, Research Administration. Technical direction was provided by Mr. J. A. Gean, Chief of Reliability, Maintainability and System Safety.

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1. SUMMARY

1.1 BASIS FOR THE ANALYSIS

The data analyses of the UH-1C, UH-1D, UH-1H, and AH-1G helicopter tail rotor systems and this report were prepared under Contract DAAJ02-72-C-0028. The use of a tail rotor system to counteract the torque of the main rotor and provide directional control has been controversial. The tail rotor system performs the function efficiently for low weight and low basic cost. However, since it is normally outside the vision of the pilot, it has been associated with a large share of the non-material-failure-caused mishaps in addition to those resulting from material failure. A study of the UH-1/AH-1 mishap data revealed that tail-rotor-associated mishaps resulted in accidents (Class 1, 2, or 3 mishaps) 1.8 times more frequently than all mishaps, regardless of the system involved. In the case of material failures, a tail rotor component failure is 2.7 times as likely to cause an accident as any system material failure. (See the glossary for the definitions of mishap and accident.) The objectives of this analysis are to develop benchmark maintenance and logistic support data for the design of future helicopter anti-torque systems and to put into better perspective the cost of tail-rotor-system-associated mishaps. The analyses were performed on data acquired from:

- UH-1/AH-1 Maintainability and Reliability (M&R) Program (1964 - 1970)
- Monitored Maintenance Task Time (February, April, May 1972)
- Component overhaul (1963 - 1970)
- Army's Maintenance and Management System (TAMMS) (1 January 1964 - 1 February 1972)
- Navy's Maintenance and Material Management (3-M) System (1 September 1965 - 1 March 1972)
- Aircraft technical manuals
- Army's Reliability and Maintainability Management Improvement Techniques (RAMMIT) program (1 January 1964 - 30 June 1970, 1 July 1971, or 31 December 1971)
- U. S. Army Agency for Aviation Safety (USAAAVS) (1 January 1967 - 31 March 1972)
- UH-1 Series Target Price Lists

Information on all four models was available from only some of the data sources.

In the analyses, the tail rotor systems were each divided into three dynamic subsystems: the tail rotor hub and blade assembly, the tail rotor drive, and the tail rotor control. Most of the analyses were conducted at the component level. The results where appropriate were combined to determine values for the subsystems and the tail rotor systems. Table I shows, at the tail rotor system level, some of the more significant values determined.

1.2 DISCUSSION OF RESULTS

The mean-time-between-failure (MTBF) values obtained from 3-M analyses on UH-1D and AH-1G components were considerably lower than those obtained from the UH-1/AH-1 Maintainability and Reliability (M&R) Program monitoring activities. Many of the unscheduled maintenance actions in the 3-M data dealt with nonfailure occurrences, the type of which was seldom reported during the period of M&R monitoring.

The mean-time-between-maintenance (MTBM) values were computed by combining the mean-time-between-scheduled-maintenance (MTBSM) values obtained from the aircraft technical maintenance manuals with the MTBF values from M&R data. The more frequent, 50-hour hub maintenance specified for the UH-1C makes its MTBM much lower than that which was determined for the other aircraft.

There appears to be a significant difference between the time required to perform a maintenance task and the time that is reported by the data systems. This difference partially results from maintenance personnel accounting for their work period by splitting their time, both active and nonactive, between the maintenance tasks performed. The average maintenance task time from the analysis of the monitoring data is less than 20 percent of the average obtained from the analysis of the 3-M data.

The only data source that contained both maintenance manhours and flight-hour values was the Navy 3-M data. The maintenance man-hours per flight hour (MMH/FH) were computed for the UH-1D and AH-1G aircraft that were loaned to and operated and maintained by the Navy. The results showed that the UH-1D system required almost 40 percent more maintenance than the AH-1G. The reason for this appears to be the large amount of maintenance performed at the intermediate level on the tail rotor hub.

TABLE I. SUMMARY OF VALUES DETERMINED FROM THE TAIL ROTOR SYSTEM DATA ANALYSIS

	Utility Helicopters		Attack Helicopters	
	UH-1D	UH-1H	UH-1C	AH-1G
MTBF (Hours)				
3-M Data	30.			21.
M&R Program Data	90.		76.	67.
MTBM (Hours)	47.4		30.2	40.1
MTBSM (Hours)	100.		50.	100.
Mean Maintenance Time ($\overline{M}$) (Calendar Hours)				
Monitored Data	0.2086		0.2115	0.2321
3-M Data	1.2500			1.1700
MMH/FH	0.1131			0.0816
Unscheduled Maintenance Actions per Million Flight Hours	11,093		13,223	14,881
Mishaps per Million Flight Hours	83.6	60.3	54.4	114.9
Average Cost per Mishap for Repair or Replacement	$44,733	$68,460	$55,482	$79,671
Total T/R System Life-Cycle Cost per Flight Hour for a 1000-Aircraft Fleet				
Including Mishap Costs	$11.44		$19.11	
Excluding Mishap Costs	$ 7.26		$ 8.40	

The unscheduled maintenance rate determined from the M&R Program data was about 34 percent higher for the AH-1G and 19 percent higher for the UH-1C than it was for the UH-1D/H. This was due to a high rate of damage to the UH-1C blades from armament debris and a higher frequency of 90° gearbox failure on the AH-1G.

A repaired versus scrapped analysis was attempted using TAMMS 2407 maintenance data. The data was found to be deficient in that the disposition of most of the items is not recorded. The disposition could be assumed for most of the maintenance actions; however, "replaced" is one of the actions for which disposition could not be assumed. Since 53 to 97 percent of the records fall into the "replaced" category, the repair versus scrapped analysis was inconclusive.

The factors that impacted the most on the tail rotor system life-cycle costs were the tail rotor system associated mishap rate and the average cost per mishap.

In the cost analysis which applied the results of the many analyses to two fleets of aircraft, utility and attack, the impact of the mishap costs increased the basic support cost for the utility helicopters by 58 percent and the attack helicopters by 128 percent. The basic life-cycle support cost in dollars per flight hour for the two types was reasonably close. Figures 1 and 2 show how the basic life-cycle support costs are divided among the various cost elements.

Since mean-time-to-removal (MTR) and mean-time-between-removals (MTBR) are values which have meaning only for the items being removed, they are not combinable for most of the tail rotor subsystems. The values (Table II) determined from the overhaul data are considerably larger than the values obtained from the RAMMIT reports. This is to be expected since many of the removals in the RAMMIT data are for nonfailure and the assemblies are subsequently reinstalled on the same or other aircraft. The overhaul data, however, includes only those removals where the assembly is forwarded to an overhaul facility. Exponential distribution analysis procedures were used in Section 6 to estimate the mean-time-between-removals ($MTBR_e$) of the assemblies reported in the RAMMIT data when the nonfailure removals are reinstalled and permitted to function until they either fail or achieve their overhaul interval or scheduled life limit. Appendix VI performs a similar analysis on the same data using a Weibull analysis procedure. It also examines the effect that off-aircraft repair has on the components' MTBR.

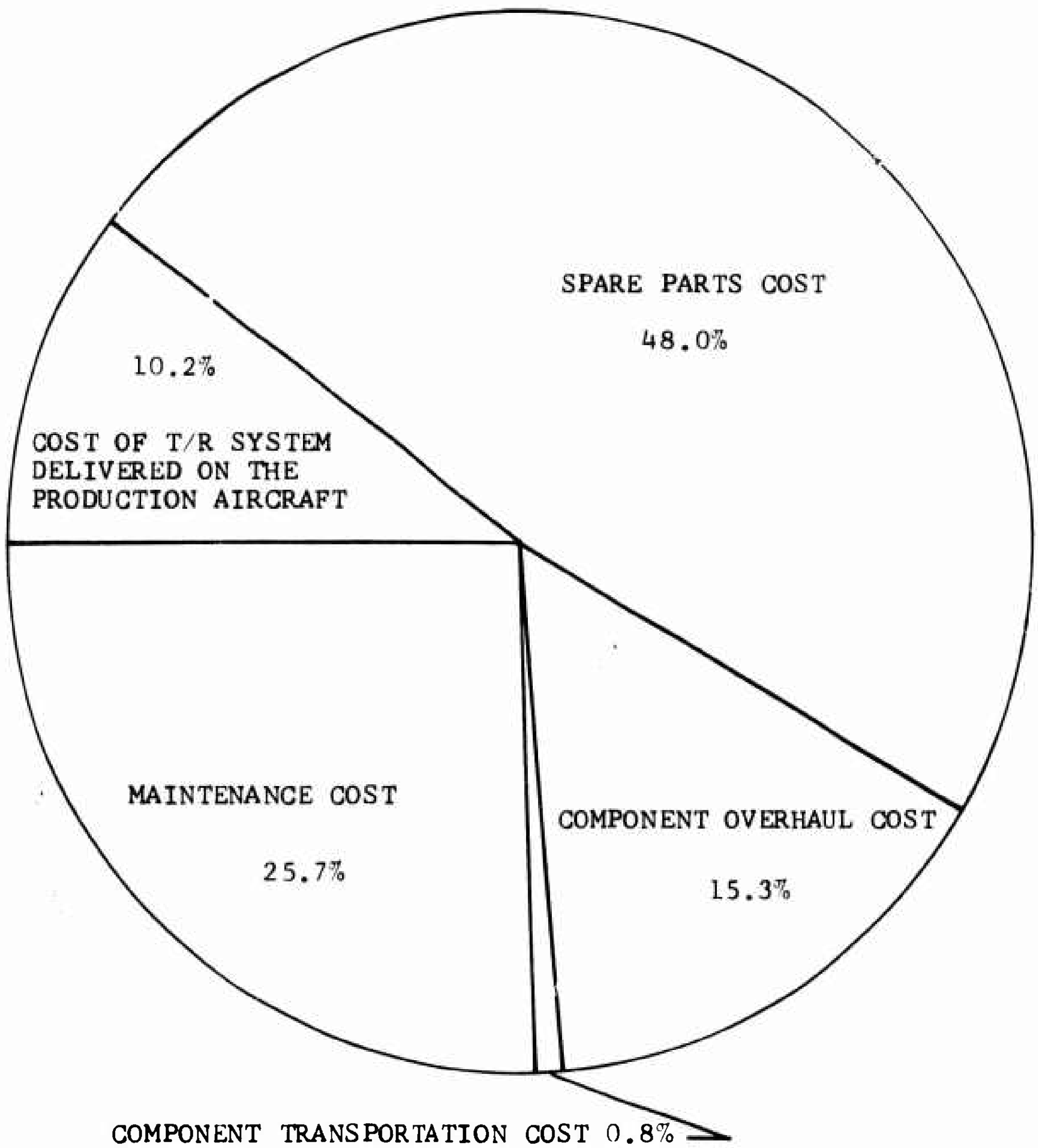


Figure 1. Distribution of the Basic Tail Rotor System Life-Cycle Cost of a Utility UH-1 Type Helicopter.

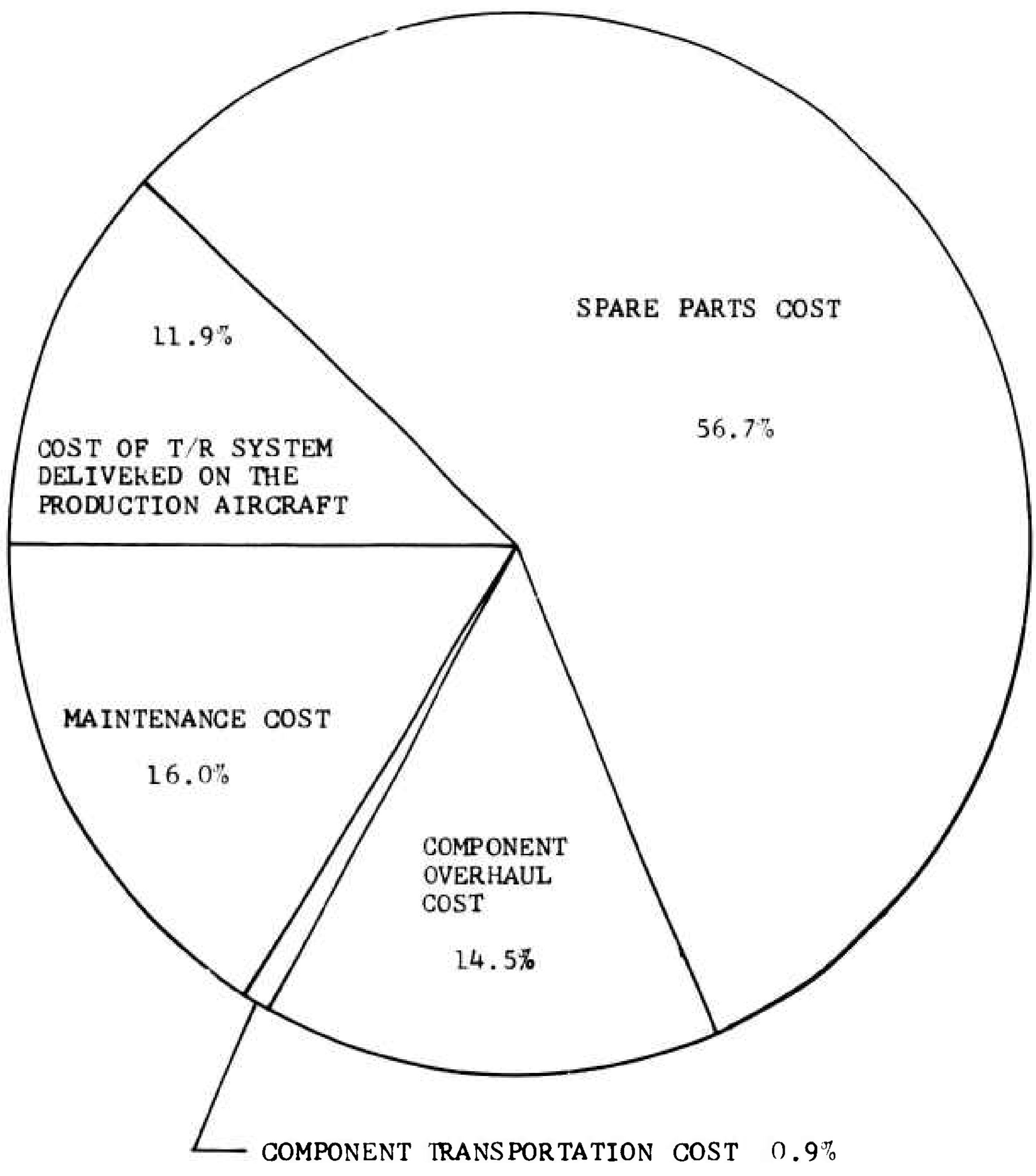


Figure 2. Distribution of the Basic Tail Rotor System Life-Cycle Cost of an Attack AH-1 Type Helicopter.

TABLE II. MTR/MTBR OF UH-1/AH-1 TAIL ROTOR SYSTEM OVERHAUL AND LIMITED LIFE COMPONENTS

Source of Data Component	All Removal Causes MTR/MTBR	Failure Cause Removals		$MTBR_e$ Section 6	$MTBR_e$ Appendix VI	MTBR* Including Repairs
		MTR	MTBR			
Component Overhaul						
42^o Gearbox	1010	718	2796	-		
90^o Gearbox	884	652	2891	-		
RAMMIT Reports						
T/R Hub	208	289	898	634	541	527
T/R Blade	298	316	857	620	596	587
42^o Gearbox	675	540	1206	858	840	829
90^o Gearbox	632	473	1253	732	720	713
Hanger Assembly	462	416	689	689	781	781

* An MTBR computed from RAMMIT report data which considers removals for failures and time change only, but includes off-aircraft repair of a fraction of the failed items and their use for replacement.

2. INTRODUCTION

This report is prepared in accordance with the requirements of Contract DAAJ02-72-C-0028, Data Analysis of the UH-1/AH-1 Tail Rotor System (DATRS).

The purpose was to study the reliability, maintainability, and safety (RMS), and cost characteristics of the tail rotor system in order to develop benchmark maintenance and logistic support data for the design of future helicopter antitorque systems. Operational, failure, maintenance, repair, accident and cost data were analyzed to provide basic RMS and cost values which establish levels to be surpassed by future antitorque systems and a basis for evaluation of improvements to current designs.

The analysis considered aircraft configuration (utility, attack), inspection and maintenance procedures, and criteria for repair or scrappage. The mission types (training, noncombat, combat) were not defined in the data sources and therefore were not considered. Operating loads, stresses, and deflectiors versus design values could not be presented because a review of the mission profile recorder data obtained under the UH-1/AH-1 Maintainability and Reliability (M&R) Program and the BHC flight test data revealed that neither of these sources provides information on tail rotor loads, stresses, and deflections under actual flight usage.

The components analyzed are listed in Table III. Those that have overhaul or retirement intervals are listed in Table IV along with their respective interval values.[1,2,3]

2.1 DATA SOURCES ANALYZED

This analysis was performed using both BHC and government-furnished data. The following paragraphs provide a brief description of the major sources.

2.1.1 BHC Data Sources

2.1.1.1 The Disassembly Inspection Summary, SAV Form 634 Data (Formerly OSM Form 634)

This is a government form on which BHC reports the overhaul, repair, and scrappage of overhaul and limited life components from military aircraft. Computer programs were prepared under the M&R Program to list and analyze the "reason-for-removal" file and the "parts-replaced and assemblies-scrapped" file. A special file of the "reasons-for-removal" data including only

TABLE III. TAIL ROTOR SYSTEM COMPONENTS

SUBSYSTEM Component	Bell Part Number	Federal Stock Number	Models Used On			
			C	D	H	G
T/R HUB & BLADE	204-011-701-009	1560-753-7298		x		
	204-011-701-015	1560-871-8678		x	x	
	204-011-701-017	1615-907-0843	x			
	204-011-800-009	None	x			
	204-011-800-011	1615-133-7363				x
	204-011-800-013	1615-133-7238	x	x	x	
	204-011-800-023	None				x
	209-010-701-001	1615-928-9014				x
Hub Assembly	204-011-701-011	1615-017-9616		x		
	204-011-701-013	1615-871-8677	x	x	x	
	204-011-701-019	1615-933-6825	x	x	x	
	204-011-701-029	1615-933-6824		x		
	204-011-801-003	1615-178-8531				x
	204-011-801-005	1615-135-0294	x	x		
	204-011-801-009	1615-133-6872	x	x	x	
	204-011-801-011	1615-176-1797				x
	209-010-701-003	1615-928-6311				x
T/R Blade	204-011-702-015	1615-472-7308		x	x	
	204-011-702-017	1615-907-0842	x			x
T/R DRIVE						
T/R Drive Shaft	204-040-620-003	1560-678-5414	x	x	x	x
	204-040-620-005	1615-019-0217		x	x	
	209-040-611-001	1615-931-2290				x
Hanger Assembly	204-040-600-007	1615-766-8578	x	x		
	204-040-600-009	1615-832-8951	x	x	x	x
42° Gearbox	204-040-003-023	1615-776-1626	x	x		
	204-040-003-037	1615-918-2676	x	x	x	x
90° Gearbox	204-040-012-007	1615-472-7305	x	x		
	204-040-012-013	1615-918-2677	x	x	x	x

TABLE III. (Cont'd)						
SUBSYSTEM Components	Bell Part Number	Federal Stock Number	Models Used On:			
			C	D	H	G
T/R CONTROL						
Chain	204-001-739-003	1615-624-6963	x	x	x	x
Quill Assembly	204-010-740-003	1615-633-0806		x	x	
	204-010-740-005	1615-815-6683	x	x	x	x
Sprocket Wheel	204-010-768-001	1615-624-6956	x	x	x	x
Control Tube	204-010-742-009	1615-886-5998	x	x	x	x
Cone Set	204-010-724-005	1615-775-3846	x	x	x	x
Static Stop	204-010-774-011	1615-083-0468	x	x	x	x
Nut	204-010-719-001	3110-624-6714	x	x	x	x
Boot	47-641-101-001	1615-503-1896	x	x	x	x
Slider	204-010-720-003	1615-859-6111	x	x	x	
	204-010-720-005	1615-929-1017				x
	204-010-720-007	1615-350-4427		x	x	x
Plate	204-010-721-003	3110-973-3512	x	x	x	x
Bearing Set	204-011-761-003	3110-056-7571	x	x	x	x
	204-011-769-001	3110-135-0563	x	x	x	x
Crosshead	204-011-711-001	1615-051-3646	x	x	x	x
Pitch Change Link	204-011-762-001	1615-086-6781	x	x	x	
	204-011-762-005	3040-877-9077				x
	204-011-762-007	1615-805-7522	x	x	x	
	KSP 9003-5	1615-805-7456				x
Rod End Bearing	204-011-763-001	3120-980-0344	x	x	x	
	204-011-763-003	3120-851-5680				x
	KSP 7007-1	3120-369-9600	x	x	x	
	KSP 7007-3	3120-248-1470				x

TABLE IV. OVERHAUL AND RETIREMENT SCHEDULE*

Component Part Numbers	Overhaul Interval (Hours)	Retirement Interval (Hours)
Tail Rotor Hub		
204-011-701-11,-13,-19,-29		
204-011-801-3,-5,-9,-11		1100
209-011-701-3		
Tail Rotor Blade		
204-011-702-11,-15,-17		1100
42° Gearbox		
204-040-003-7,-37	1500	
90° Gearbox		
204-040-012-7,-13	1100	

*Per References 18,19 and 20.

the records which were "first removals" from aircraft which have already attained 1100 hours' flying time has also been created. The 1100-hour value was chosen because this is the aircraft overhaul interval for most of the UH-1/AH-1 components for which an overhaul interval has been specified.

2.1.1.2 UH-1/AH-1 Maintainability and Reliability (M&R) Program Data

These data consist of information obtained by reliability field engineers while monitoring UH-1C/D/H and AH-1G helicopters. The Field Failure/Discrepancy Reports (FDR), one type of data collected under the M&R Program, were a source for failure rates, mean-time-between-failure values and failure modes used in this analysis report.

2.1.1.3 Monitored Maintenance Task Time Data

To obtain maintenance task time information for DATRS, monitoring programs were conducted by Reliability engineers at three locations:

- BHC Flight Test Facility
- Lowe Army Airfield, Fort Rucker, Alabama
- Hunter Army Airfield, Fort Stewart, Georgia

The BHC Flight Test Facility provided a maintenance mechanic and two aircraft for the simulation of the removal and installation actions of the tail rotor components in accordance with Army maintenance manual instructions. These actions were repeated four times. They were observed and timed, and the average maintenance times were calculated.

The Lowe Army Airfield monitoring effort was accomplished from 1 May 1972 to 5 May 1972. Maintenance actions were performed by Page Aircraft Maintenance, Incorporated (PAMI), a civilian maintenance contractor at Fort Rucker. The maintenance activities monitored included:

- 100-hour Scheduled Inspection
- Tail Rotor Hub and Blade Assembly Balancing
- Miscellaneous Unscheduled Maintenance

The Hunter Army Airfield monitoring was accomplished during the period 15 April 1972 - 30 April 1972. This effort included about eight days observation in the organizational maintenance area, and two days at the oil analysis laboratory and the direct

support/general support prop rotor shop. Army personnel performed the maintenance at these locations.

The task times obtained from the monitoring at these three locations were averaged where possible. However, the tasks were not always performed in the same sequence of subtasks. This resulted in portions of tasks or combinations of subtasks being timed at different points in the total task.

2.1.1.4 Bell Helicopter Company UH-1 Series Target Price List

Five Target Price Lists covering contract periods FY'67 through FY'72 were used to obtain spare parts cost values for the Cost Analysis (see Table LIV).

2.1.2 Government-Furnished Data

2.1.2.1 The Army Maintenance Management System (TAMMS) Data

These data are supplied on magnetic tape to BHC as Government-furnished data under other contracts. BHC has received Maintenance Request (DA Form 2407), Equipment Maintenance Record (Organizational) (DA Form 2408-3), and Component Removal and Repair/Overhaul Record (DA Form 2410) data. Working data files have been created from the raw data tapes by the selection of appropriate records.

In addition, certain Army prepared Reliability and Maintainability Management Improvement Techniques (RAMMIT) reports based on TAMMS data were used. They were the Major Item Removal Frequency (MIRF)[4,5,6] and the Major Item Special Study (MISS) reports.[7 thru 13]

2.1.2.2 U.S. Army Agency for Aviation Safety (USAAAVS) Data

BHC has received records of UH-1/AH-1 accidents since 1963 from U.S. Army Agency for Aviation Safety (USAAAVS). These data are received on IBM cards. There was a change in the format of these cards starting 1 January 1967; therefore, only data subsequent to this date were used for this analysis. Due to the large number of cards received since 1967, these data have been placed on magnetic tape to facilitate computer analysis of the data.

2.1.2.3 Army Technical Manuals

Technical manuals[1,2,3] were used to obtain description of maintenance procedures, including inspection instructions and repair/replacement criteria.

2.1.2.4 Naval Aviation Maintenance and Material Management (3-M) Data

Currently, the 3-M data bank at BHC contains over 1.5 million records on BHC aircraft purchased by the Navy or loaned to the Navy by one of the other services. These data were derived from Support Action Form (SAF), Maintenance Action Form (MAF), Technical Directive Compliance Form (TDCF), and Equipment Statistical Data (ESD) cards. Additional working files containing UH-1D and AH-1G data have been created from the raw data by card code selection and segregation.

The data have been analyzed to obtain failure rates, task times and maintenance man-hour-per-flight-hour ratios.

2.2 TAIL ROTOR SYSTEM DESCRIPTION

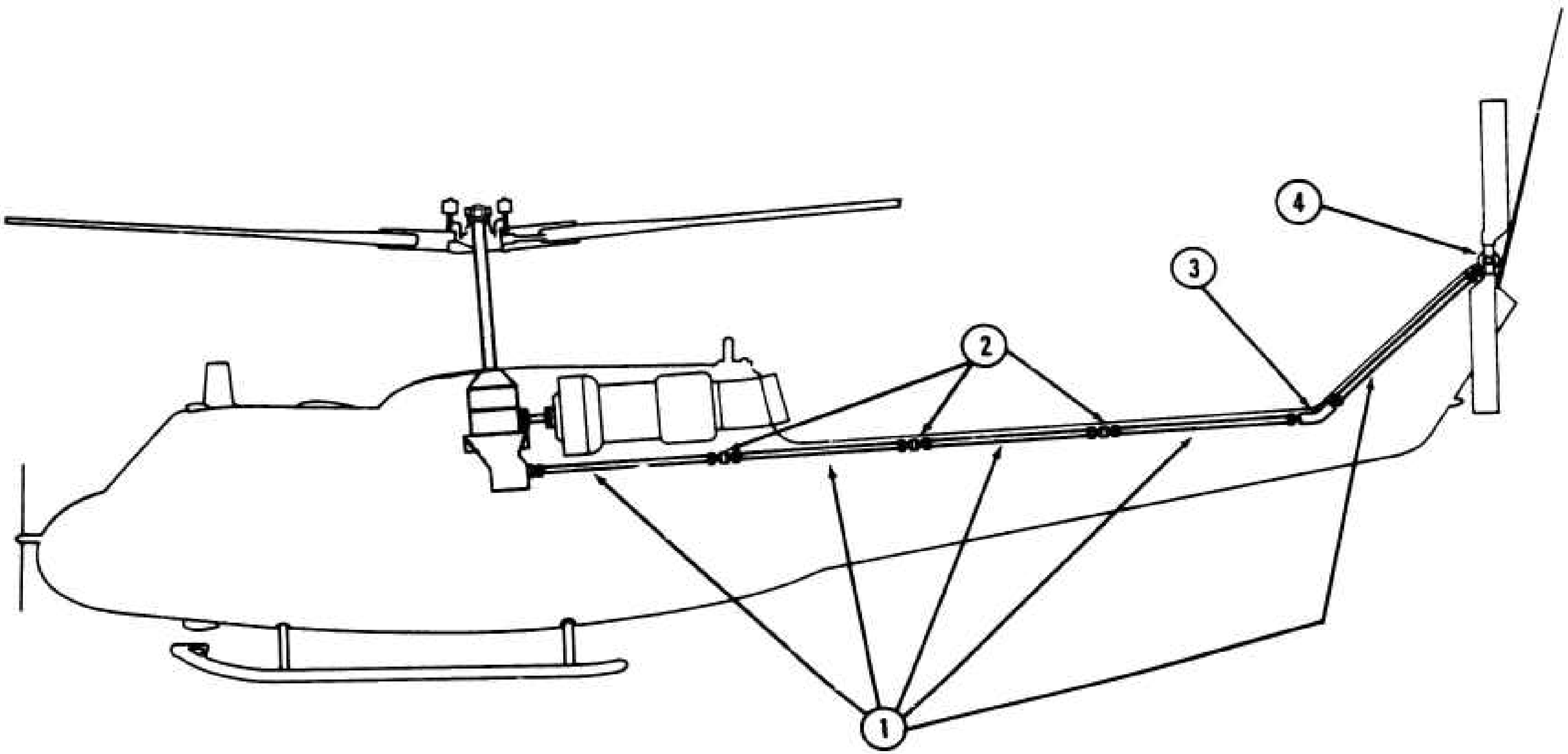
The tail rotor system (see Figure 3) counteracts the torque of the main rotor and provides directional control. The UH-1/AH-1 tail rotor system as defined in this report consists of three subsystems:

- tail rotor drive
- tail rotor hub and blade
- tail rotor control

2.2.1 Tail Rotor Drive

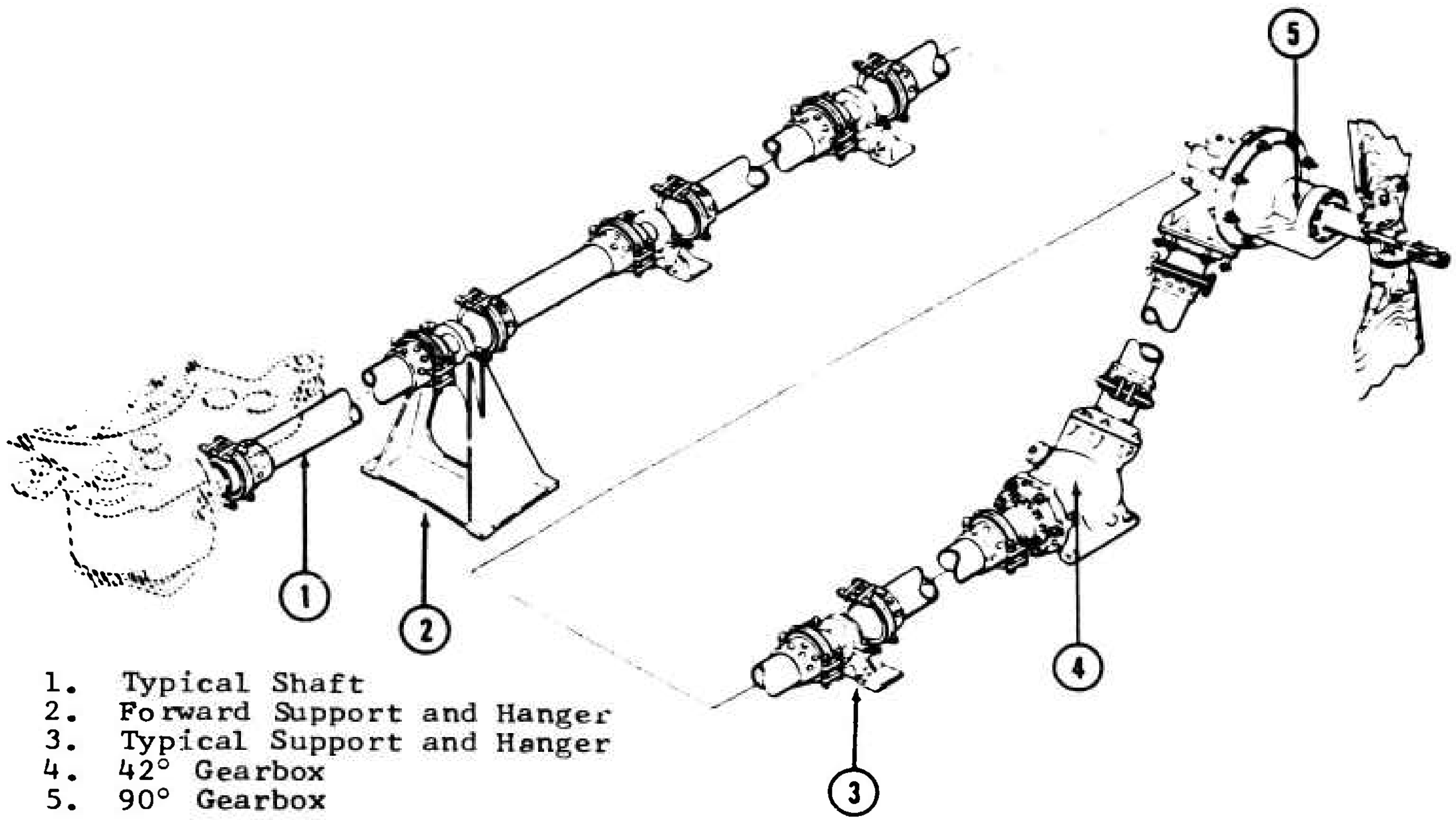
The tail rotor drive (see Figure 4) consists of the drive shafts and hanger assemblies, the 42-degree gearbox, and the 90-degree gearbox. Five identical drive shaft sections are incorporated in the power train aft of the transmission. These drive shafts, three bearing hanger assemblies, the 42-degree gearbox on the tail boom and the 90-degree gearbox on the verical fin transmit the power to drive the tail rotor. An additional shorter drive shaft section and hanger assembly are provided on helicopters with 48-foot main rotor (Models UH-1D/H). Each drive shaft consists of an anodized aluminum alloy tube with a curvic-splined coupling riveted on each end. The forward shaft extends through a tunnel between the engine firewalls, with ends connected by V-band clamps to mating splined couplings on the transmission tail rotor drive quill and on the forward hanger assembly. Other shafts are mounted in similar manner along the tail boom and fin between the hangers and gearboxes.

The hanger assemblies consist of couplings on a short splined shaft, mounted through a single-row sealed ball bearing in a



1. Tail Rotor Drive Shafts
2. Tail Rotor Hangers
3. 42° Gearbox
4. 90° Gearbox

Figure 3. UH-1/AH-1 Tail Rotor System Diagram.



1. Typical Shaft
2. Forward Support and Hanger
3. Typical Support and Hanger
4. 42° Gearbox
5. 90° Gearbox

Figure 4. UH-1/AH-1 Tail Rotor Drive System Diagram.

ring-shaped hanger, equipped with two mounting lugs for attachment on a support fitting.

The 42-degree gearbox is located on the tail boom, at the base of the vertical fin. This gearbox provides a 42-degree change in direction of the tail rotor drive, with no speed change. The gearbox assembly consists of a case with a gear quill in each end. The case is fitted with an oil filler cap, a vent breather, an oil level sight gage, and a drain plug equipped with a magnetic insert or an electric chip detector. Input and output quills have flexible couplings for the attachment of drive shafts. Access to the gearbox is provided by a vented cover fairing which has quick-release fasteners.

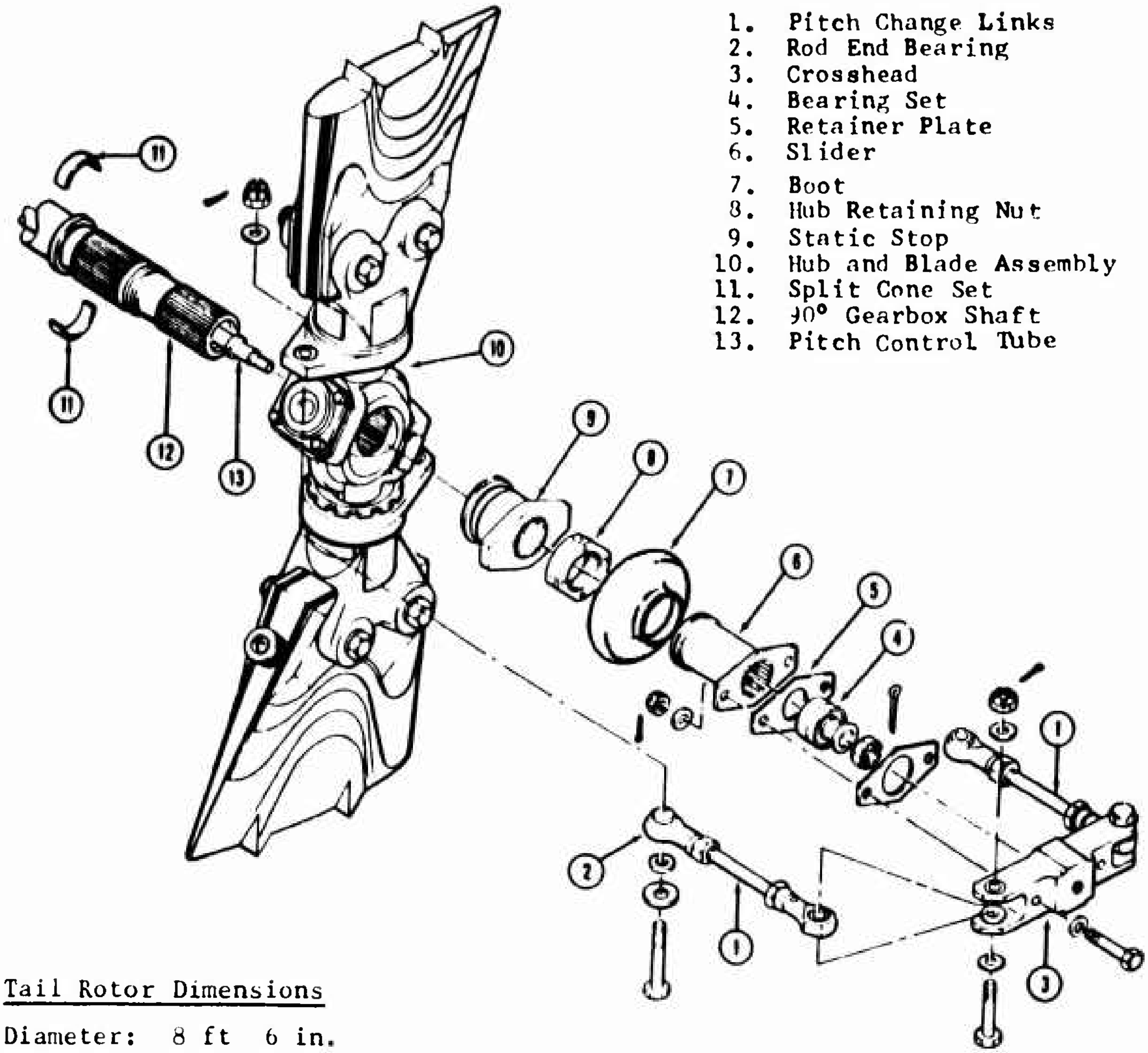
The 90-degree gearbox at the top of the tail boom vertical fin provides 90-degree change in direction of drive and 2.6:1 speed reduction between its input drive shaft and the output shaft on which the tail rotor is mounted. The gearbox has mating input and output gear quill assemblies set into a gear case provided with a vented oil filler cap, an oil level sight gage, and a drain plug which has a magnetic insert plug or an electric chip detector. The input quill has a flexible coupling for attachment of the driveshaft.

2.2.2 Tail Rotor Hub and Blade

The hub and blade assembly (see Figure 5) is a single two-blade controllable pitch tail rotor located on the left side of the tail fin. Two blades, the hub, and attaching hardware comprise the assembly. It is driven by the tail rotor gearbox. The blades are constructed of metal and are attached by bolts to blade grips which are mounted through bearings to spindles of a hub yoke. The tail rotor hub is hinge-mounted to provide automatic equalization of thrust on advancing and retreating blades. Pitch change links provide equal and simultaneous pitch change to both blades.

2.2.3 Tail Rotor Control

Tail rotor blade pitch control is accomplished by means of a control quill assembly (see Figure 6) mounted into the right side of the tail rotor gearbox, with a control tube extending through the hollow shaft on which the tail rotor is mounted. The control quill sprocket is operated by a chain attached to control cables and is engaged to the control tube through a worm thread, so that rotation of the sprocket is transmitted through the tube as linear motion to a crosshead which is connected to tail rotor blade grips by the pitch change links (see Figure 5).

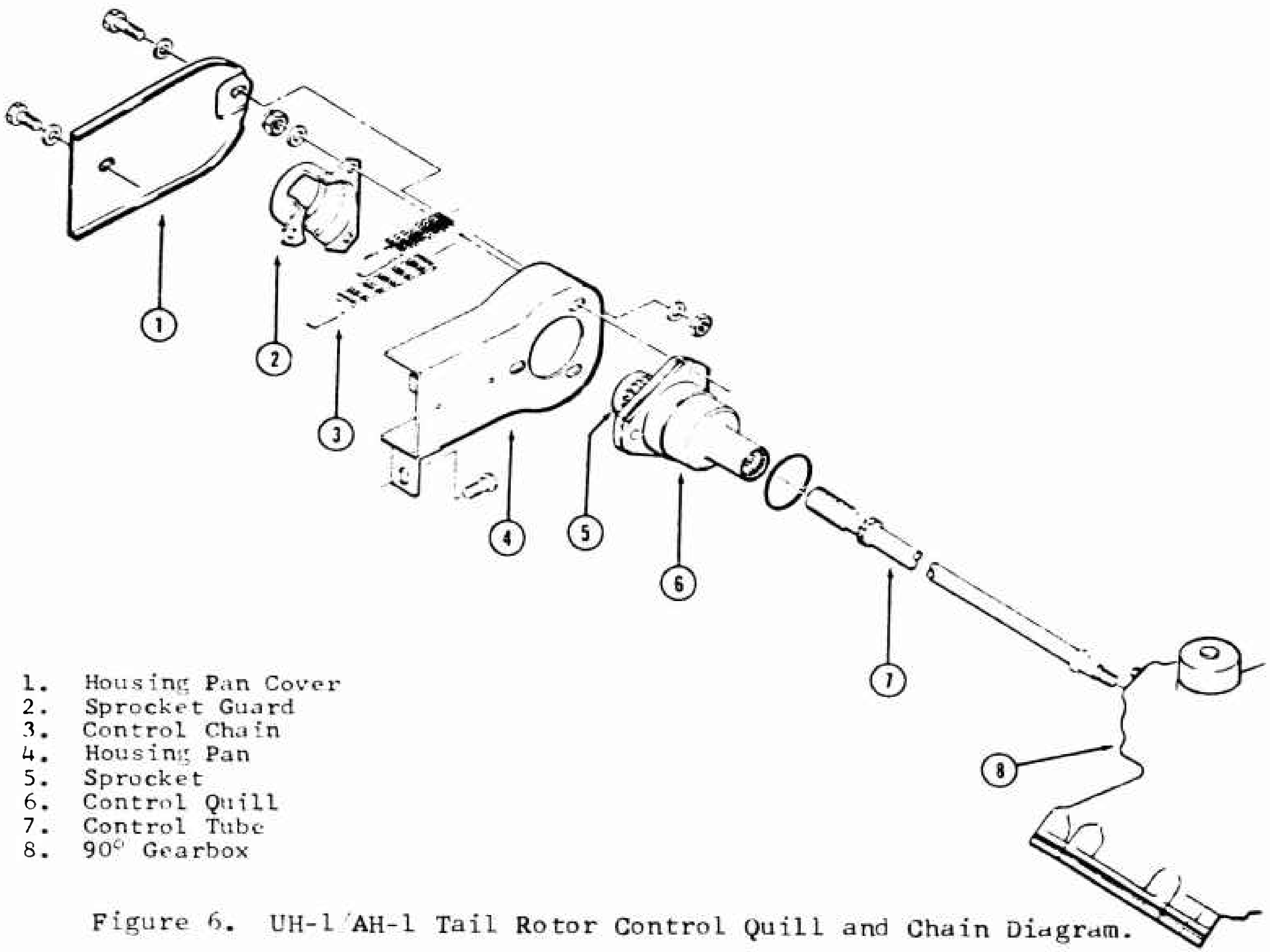


1. Pitch Change Links
2. Rod End Bearing
3. Crosshead
4. Bearing Set
5. Retainer Plate
6. Slider
7. Boot
8. Hub Retaining Nut
9. Static Stop
10. Hub and Blade Assembly
11. Split Cone Set
12. 90° Gearbox Shaft
13. Pitch Control Tube

<u>Tail Rotor Dimensions</u>

Diameter: 8 ft 6 in.
Chord: 8.41 in.

Figure 5. UH-1/AH-1 Tail Rotor Hub and Blade Assembly and Pitch Control Mechanism Diagram.



1. Housing Pan Cover
2. Sprocket Guard
3. Control Chain
4. Housing Pan
5. Sprocket
6. Control Quill
7. Control Tube
8. 90° Gearbox

Figure 6. UH-1/AH-1 Tail Rotor Control Quill and Chain Diagram.

2.3 INFORMATION COMPILED

The information compiled for this DATRS report was divided into ten smaller analyses, each of which is presented in a separate section (Sections 3 through 12). Each section is divided into two major parts--the analysis approach and the analysis results. Any conclusions which have been observed are included in the results. Additionally, more detailed information is presented in the appendixes.

The following comments concern some of the analyses:

- The mean-time-to-removal (MTR) analysis was expanded to include mean-time-between-removals (MTBR).

- The failure modes analysis is a history of the failures which are known to have occurred rather than the usual prediction type of failure modes and effects analysis.

- The cost analyses presented are for typical fleets of UH-1 (utility) and AH-1 (attack) helicopters. The wide variation in fleet size, use rate, use environment, spares cost, and repair cost over the period of data analyzed precluded the possibility of establishing the actual support costs for any given model.

3. MEAN-TIME-BETWEEN-FAILURES (MTBF) ANALYSIS

3.1 MTBF ANALYSIS APPROACH

In order to determine the MTBF of an item, it is necessary to have an adequate time base during which the failures are observed. For this reason the analysis was based on M&R Program FDR data and Navy 3-M data. The FDR data were obtained by monitoring a representative group of aircraft and recording the flight times and failure information as they occurred. FDR data are available on Models UH-1C/D/H and AH-1G. 3-M data were gathered by Navy personnel on all aircraft flown by them and represent the total picture for these aircraft. 3-M data are available on Models UH-1D and AH-1G because these models were on loan to the Navy by the Army.

The MTBF is the sum of the item operating times accumulated on all items of a given type divided by the number of failures of that item. In this analysis a failure is defined as any occurrence requiring unscheduled maintenance. The item operating times are obtained by multiplying the number of items on each aircraft times the sum of the aircraft flight hours of the group of aircraft on which the items failed.

$$\text{MTBF} = \frac{k \sum_{j=1}^{m} t_j}{f} \qquad (1)$$

where t_j = total flight hours of the jth aircraft
m = number of aircraft in th group
k = number of items on each aircraft
f = number of item failures

All of the parts listed in Table III are considered critical because a functional failure of any one of the parts will cause failure of the subsystem.

The failure rate (λ) of an item is equal to the reciprocal of its MTBF if the failures are assumed to occur randomly:

$$\lambda = \frac{1}{\text{MTBF}} = \frac{f}{k \sum_{j=1}^{m} t_j} \qquad (2)$$

3.2 MTBF ANALYSIS RESULTS

Table V presents a comparison of the MTBF values and failure rates of the subsystems and the total tail rotor system from the two data sources. The total system MTBF values derived from Navy 3-M data, Table VI, are about one-third of the comparable values obtained from the M&R data, Table VII. The flight time on which the 3-M data are based is 44 percent of the M&R time base for AH-1Gs and 52 percent of the M&R time base for UH-1D/Hs.

The 3-M analyses indicate that most of the tail rotor system failures occur in the hub and blade and drive subsystems, while the M&R data indicate that most of the failures are in the control subsystem. However, the 3-M data show a significant frequency of maintenance actions to correct rotor unbalance which was not as thoroughly reported during the M&R program. The M&R program emphasis was placed more on the reporting of component failures. Conditions which required only unscheduled maintenance adjustments had a lower priority.

In the 3-M analysis, two conditions, both probably related to the age of the aircraft, appeared to cause the MTBF of the UH-1D hub and blade assemblies to be lower than that of the AH-1G assemblies. The data show that the rate of hub wear and rotor unbalance was higher on the UH-1D than on the AH-1G. The UH-1D aircraft (FY 1965 and 1966) were two to three years older than the AH-1G aircraft (primarily FY 1968).

In Section 6, the MTR/MTBR analyses, additional MTBF values have been computed for the tail rotor system overhaul and time change components. Table VIII compares the MTBF values from the four data sources for these components. The comparison shows that the 3-M data produced the lower values and the M&R data produced the higher values. For some components the M&R data values and the RAMMIT MIRF data values were in general agreement.

TABLE V. COMPARISON OF 3-M AND M&R PROGRAM TAIL ROTOR SYSTEM MTBF VALUES

Subsystem	3-M						M&R								
	D			G			D/H			C			G		
	MTBF (Hr)	λ_m	%	MTBF (Hr)	λ_m	%	MTBF (Hr)	λ_m	%	MTBF (Hr)	λ_m	%	MTBF (Hr)	λ_m	%
Tail Rotor Hub & Blade	57	17,453	52	88	11,407	24	414	2,415	22	155	6,450	49	381	2,625	18
Tail Rotor Drive	87	11,495	35	34	29,277	61	234	4,265	38	267	3,750	28	164	6,108	41
Tail Rotor Control	240	4,153	13	134	7,427	15	227	4,413	40	331	3,023	23	163	6,148	41
Total Tail Rotor System	30	33,101	100	21	48,111	100	90	11,093	100	76	13,223	100	67	14,881	100

λ_m = the failure rate in failures per million flight hours

% = subsystem failure rate as a percentage of Total Tail Rotor System failure rate

TABLE VI. COMPONENT MTBF FOR THE UH-1D/AH-1G TAIL ROTOR SYSTEM

(3-M Data Through February 1972)

SUBSYSTEM Component	UH-1D MTBF (Hours)	AH-1G MTBF (Hours)
T/R HUB & BLADE	57	88
T/R Hub	83	209
T/R Blade*	764	988
Other	352	217
T/R DRIVE	87	34
T/R Drive Shaft**	3,472	1,325
Hanger Assembly***	1,348	198
42° Gearbox	539	245
90° Gearbox	304	204
Other	604	686
T/R CONTROL	240	134
Control Quill	5,778	3,351
Control Tube	20,226	4,308
Pitch Control Mechanism	3,111	1,077
Chain	4,045	1,160
Pitch Change Link*	1,154	602
Crosshead	612	558

* Two per aircraft
** Six per aircraft on UH-1D, five per aircraft on AH-1G
*** Four per aircraft on UH-1D, three per aircraft on AH-1G

TABLE VII. COMPONENT MTBF FOR THE UH-1D/H/C, AH-1G TAIL ROTOR SYSTEM
(Based on M&R Data)

SUBSYSTEM Component	MTBF (Hours) UH-1D/H	UH-1C	AH-1G
T/R HUB & BLADE	414	155	381
T/R Hub	1,876	2,976	1,368
T/R Blade*	1,159	365	1,122
Other	6,410	1,592	8,929
T/R DRIVE	234	267	164
T/R Drive Shaft**	10,204	12,820	3,891
T/R Hanger Assembly***	1,605	1,553	2,049
42° Gearbox	2,083	2,551	1,088
90° Gearbox	1,418	965	442
Other	-	-	4,274
T/R CONTROLS	227	331	163
T/R Boot	3,086	5,952	926
T/R Slider	2,571	1,021	2,012
T/R Crosshead	3,846	-	2,538
Crosshead Bearing Set	3,508	7,143	4,902
T/R Pitch Change Link*	1,093	1,931	938
T/R Chain	1,927	8,929	1,342
T/R Quill	2,653	5,102	1,244
T/R Control Tube	4,525	35,714	13,699
Other	4,525	2,825	4,566

* Two per aircraft

** Five per aircraft on UH-1C and AH-1G, Six per aircraft on UH-1D/H

*** Three per aircraft on UH-1C and AH-1G, Four per aircraft on UH-1D/H

TABLE VIII. COMPARISON OF MTBF VALUES DETERMINED FROM FOUR DATA SOURCES

Component	Model	M&R Data	3M Data	Bell O/H Data	RAMMIT MIRF Data
Tail Rotor Hub	UH-1C	2976	-	-	-
	UH-1D	-	83	-	-
	UH-1D/H	1876	-	-	1004
	AH-1G	1368	209	-	569
	D/H/G	-	-	-	898
Tail Rotor Blade	UH-1C	365	-	-	-
	UH-1D	-	764	-	-
	UH-1D/H	1159	-	-	924
	AH-1G	1122	988	-	638
	D/H/G	-	-	-	857
42° Gearbox	UH-1C	2251	-	-	-
	UH-1D	-	539	-	-
	UH-1D/H	2083	-	-	1271
	AH-1G	1088	245	-	924
	D/H/G	-	-	-	1206
	C/D/H/G	-	-	718	-
90° Gearbox	UH-1C	965	-	-	-
	UH-1D	-	304	-	-
	UH-1D/H	1418	-	-	1311
	AH-1G	442	204	-	982
	D/H/G	-	-	-	1253
	C/D/H/G	-	-	652	-
Hanger	UH-1C	1553	-	-	-
	UH-1D	-	1348		-
	UH-1D/H	1605	-	-	693
	AH-1G	2049	198	-	652
	D/H/G	-	-	-	689

4. MEAN-TIME-BETWEEN-(SCHEDULED AND UNSCHEDULED) MAINTENANCE (MTBM) ANALYSIS

4.1 MTBM ANALYSIS APPROACH

The MTBM is the mean-time-between-maintenance for all maintenance actions (scheduled and unscheduled) performed on the tail rotor system. The tail rotor system mean-time-between-scheduled maintenance (MTBSM) was determined from data in the organizational maintenance manuals[1,2,3] for Models UH-1C/D/H and AH-1G helicopters. These TMs specify the scheduled maintenance tasks and the periodic requirement for their performance.

Table IX shows the scheduled maintenance requirements extracted from the TMs. Note that the servicing tasks performed during daily inspections were not included in this analysis.

For UH-1 and AH-1 helicopters, maintenance tasks are scheduled to be performed at multiples of either the intermediate inspection periods (25-hour intervals) or the periodic inspections (100-hour intervals). To determine the MTBSM for a tail rotor system component, the approach is somewhat different from that used to determine MTBF. Where several different scheduled actions are specified for a component, each with a different period interval, those actions occurring at the same scheduled time are considered dependent (or combined) rather than independent actions.

For example, a 42-degree gearbox requires servicing (action A) every 100 hours and greasing (action B) every 500 hours. Since every time action B is performed, action A is also performed, the MTBSM is 100 hours.

Following this approach, the MTBSM for each component is the smallest of the established time between maintenance for any specified maintenance actions for that component. Similarly, the MTBSM for the tail rotor system is the smallest of the MTBSM values for the tail rotor components.

The MTBF values from MWR data, presented in the MEAN-TIME-BETWEEN-FAILURES ANALYSIS, Section 3, were combined with the MTBSM values to obtain the MTBM as follows:

$$\mathrm{MTBM} = \frac{1}{\frac{1}{\mathrm{MTBF}} + \frac{1}{\mathrm{MTBSM}}} \qquad (3)$$

This equation assumes that the failure rate is constant and that the data is from mature aircraft.

TABLE IX. FREQUENCY OF SCHEDULED MAINTENANCE ACTIONS FOR MODELS UH-1C/D/H AND AH-1G HELICOPTERS

SUBSYSTEM Component	Grease	Service	Balance	TBO	Retirement Life
T/R HUB & BLADE			100		
Hub	100*	-		-	1100
Blade	-	-	-	-	1100
T/R DRIVE					
42° Gearbox	500	100	-	1500	-
90° Gearbox	500	100	-	1100	-
Hanger Assembly	500	-	-	-	-
T/R CONTROL					
Crosshead Bearing Set	100	-	-	-	-

* On Model UH-1C this is done every 50 hours.

4.2 MTBM ANALYSIS RESULTS

Table X presents the mean-time-between-scheduled maintenance for the tail rotor system. Table XI presents the results of the MTBM analysis for the M&R Program FDR data. The results show that the MTBM values for the UH-1D/H and the AH-1G are fairly comparable, while the UH-1C is more than 25 percent lower because of its more frequent hub maintenance and lower tail rotor blade MTBF. During the M&R Program, the UH-1C tail rotor blade was subjected to frequent armament debris damage from hand-held door guns. This condition was improved later when a pintle mount and brass catches were made available.

TABLE X. MEAN-TIME-BETWEEN-SCHEDULED MAINTENANCE FOR THE TAIL ROTOR SYSTEM

SUBSYSTEM Components	AIRCRAFT MODEL		
	UH-1D/H	UH-1C	AH-1G
T/R HUB & BLADE	100	50	100
T/R Hub Assembly	100	50	100
T/R Blade	100	100	100
T/R DRIVE	100	100	100
T/R Drive Shaft	-	-	-
T/R Hanger Assembly	500	500	500
42° Gearbox	100	100	100
90° Gearbox	100	100	100
T/R CONTROL	100	100	100
Crosshead Bearing Set	100	100	100
TOTAL T/R SYSTEM	100	50	100

TABLE XI. MEAN-TIME-BETWEEN-MAINTENANCE FOR THE TAIL ROTOR SYSTEM (Based on M&R Data)

SUBSYSTEM Components	AIRCRAFT MODEL		
	UH-1D/H	UH-1C	AH-1G
T/R HUB & BLADE	80.5	37.8	79.2
T/R Hub Assembly	94.9	49.2	93.2
T/R Blade	92.1	78.5	91.8
T/R DRIVE	70.1	72.8	62.1
T/R Drive Shaft	10,204	12,820	3,891
T/R Hanger Assembly	381.2	378.2	401.9
42° Gearbox	95.4	96.2	91.6
90° Gearbox	93.4	90.6	81.5
T/R CONTROL	69.4	76.8	62.0
Crosshead Bearing	97.2	100.0	96.2
TOTAL T/R SYSTEM	47.4	30.2	40.1

5. MAINTAINABILITY INDEXES

5.1 MAINTAINABILITY INDEXES ANALYSIS APPROACH

The maintainability indexes "are the means for determining whether or not the maintainability requirement in an overall specification for a system has been complied with."[20] In arriving at these indexes, units of time are the most useful measures of success. The overall reference is the period of time when the system is operable as against the period when the system is not operable (downtime).

Downtime consists of active downtime and delay downtime. Active downtime is the actual time spent performing maintenance, inspection, repair, replacement, check-out, etc. Delay downtime is the period when a system is inoperable due to unavailability of tools, test equipment, spare parts and other administrative delays. The basic element of the maintainability indexes is the repair time R_t, which is defined as the period of active downtime required to return a failed system to normal operation.

The indexes developed in this section are for organizational maintenance actions only.

The maintenance times used were those acquired during the monitoring of tail rotor maintenance which was performed as a part of this study. The maintenance procedures in Appendix I provided a means of calculating time values for a series of actions. The maintenance times from the Navy 3-M data were used for comparison. The TAMMS data could not be used because it was not possible to obtain maintenance times in calendar hours from this source.

5.1.1 Mean-Time-To-Repair (MTTR)

The MTTR is the average downtime in calendar hours for a specified unscheduled task. The maintenance tasks were grouped into the following maintenance actions:

Remove	Track
Replace (Install)	Grease
Align (Rig)	Service

To determine the mean time to repair for specific actions $MTTR_A$ on like items within the tail rotor system, the following equation was used:

$$\mathrm{MTTR}_{A_j} = \frac{\sum_{i=1}^{n_j} R_{t_i}}{n_j} \qquad (4)$$

where n_j = the number of failures that require a specific maintenance action j to correct on like items

R_{t_i} = the repair time for the ith failure repair of a specific corrective action j on like items

However, to find the MTTR of any item, it was necessary to consider the frequency with which each type of action occurred. By examining the TAMMS 240? data, it was possible to determine the percentage of all maintenance actions on a component that fell into each action category for that component. The following equation was used to determine the component mean time to repair MTTR_C.

$$\mathrm{MTTR}_{C_k} = \frac{\sum_{j=1}^{n_k} P_j \, \mathrm{MTTR}_{A_j}}{100} \qquad (5)$$

where P_j = the percentage of all unscheduled maintenance actions performed on the component which are action type j

n_k = the number of different type actions j on component k

To determine system and subsystem MTTR values, it was necessary to consider the rates at which failures of the various components occurred. The component failure rate values used are from the M&R data.

Table V expresses these rates as failures per million flight hours (λm). The value for "other" items was not considered because R_t for these items is not known. The following equation was used to obtain the subsystem mean time to repair MTTR_{SS}.

$$\mathrm{MTTR}_{SS} = \frac{\sum_{k=1}^{n_L} a_{kL} \lambda_k \mathrm{MTTR}_{C_k}}{\sum_{k=1}^{n_L} a_{kL} \lambda_k} \qquad (6)$$

where n_L = the number of different types of components within the subsystem L

a_{kL} = the number of components of type k within the system L

λ_k = the failure rate for component type k within the subsystem L

Similarly, the system mean time to repair $MTTR_S$ is obtained by using the following equation:

$$MTTR_S = \frac{\sum_{L=i}^{m} \lambda_L \, MTTR_{SS}}{\sum_{L=i}^{m} \lambda_L} \qquad (7)$$

where m = the number of subsystems within the tail rotor system

λ_L = the failure rate of subsystem L determined by

$$\lambda_L = \sum_{k=1}^{n_L} a_{kL} \lambda_k \qquad (8)$$

5.1.2 Mean Preventive Maintenance Action Time ($\overline{M}_{pt}$)

In order to reduce the probability that a system will require corrective maintenance action, this system is taken out of operation for a period of time for preventive maintenance (lubrication, calibration, adjustment, etc.). The mean preventive action time $\overline{M}_{pt}$ is defined as the statistical mean of the sum of the times required for preventive actions divided by the number of these actions scheduled for a given period. For this report the scheduled maintenance actions for 1500 flight hours of helicopter operation were considered. This time was selected because it is the greatest allowable operating time for an item (42-degree gearbox) within the tail rotor system. Daily and preflight inspections are excluded.

The number of preventive maintenance actions n_p was determined using the mean-time-between-scheduled-maintenance values MTBSM presented in Table X. The number of scheduled actions on a component $n_{p_{C_k}}$ in a 1500-hour period is expressed by

$$n_{p_{C_k}} = a \sum_{i=1}^{s} n_{p_{A_i}} \tag{9}$$

where s = the number of types of scheduled maintenance actions i on the component

a = the number of like components k on the aircraft

$n_{p_{A_i}}$ = the number of scheduled actions of type i on the component k in 1500 hours where generally

$$n_{p_{A_i}} = \frac{1500}{MTBSM_{A_i}} \tag{10}$$

When the action involves the removal and installation of a component (tail rotor balancing, TBO replacements, etc.), the removal and installation are considered as two different actions.

The number of preventive maintenance actions in 1500 hours for the subsystem $n_{p_{SS}}$ is determined by

$$n_{p_{SS}} = \sum_{k=1}^{n_L} n_{p_{C_k}} + 60 \tag{11}$$

where n_L = the number of different k components within the subsystem L

There are 60 inspections of each subsystem in 1500 hours: an intermediate every 25 hours and a periodic every 100 hours. The time for these is not included in the number of component actions.

The number of preventive actions for the system in 1500 hours n_{p_S} is expressed by

$$n_{p_S} = \sum_{L=1}^{m} n_{p_{SS_L}} + 60 \tag{12}$$

where m = the number of L subsystems within the system

The additional 60 actions are those used in inspecting the exterior and opening and closing access doors during the intermediate and periodic inspections. These actions were not charged to any particular subsystem.

Using the preventive maintenance action times obtained during the monitoring, the following equations were used to find the mean preventive maintenance action time $\bar{M}_{pt}$ for the component, subsystem, and system. The mean preventive maintenance action time for the component k is expressed by

$$\bar{M}_{pt_{C_k}} = \frac{\sum_{i=1}^{s} \left(\bar{M}_{pt_{A_i}}\right)\left(n_{p_{A_i}}\right)}{n_{p_{C_k}}} \tag{13}$$

where s = the number of types of preventive maintenance actions on the component

$\bar{M}_{pt_{A_i}}$ = the mean time required for the ith preventive maintenance action of type i on component k

$n_{p_{C_k}}$ = the number of preventive maintenance actions occurring on the component k in 1500 flight hours

The mean preventive maintenance action time for the subsystem L is expressed by

$$\bar{M}_{pt_{SS}} = \frac{\left[\sum_{k=1}^{n_L} \left(n_{p_{C_k}}\right)\left(\bar{M}_{pt_{C_k}}\right)\right] + 60 \quad I_{SS}}{n_{p_{SS}}} \tag{14}$$

where I_{SS} = the mean preventive maintenance action time for the inspection of the subsystem

The mean preventive maintenance action time for the system is expressed by

$$\bar{M}_{pt_S} = \frac{\left[\sum_{L=1}^{m} \left(n_{p_{SS_L}}\right)\left(\bar{M}_{pt_{SS_L}}\right)\right] + 60 \quad I_S}{n_{p_S}} \tag{15}$$

where I_S = the mean preventive maintenance action time for the inspection of the system

5.1.3 Mean Corrective and Preventive Action Time ($\overline{M}$)

5.1.3.1 Monitored Data

The $\overline{M}$ (active system downtime resulting from both corrective and preventive activities) was calculated for each subsystem using the following equation:

$$\overline{M} = \frac{\left(n_c\right) MTTR_S + \left(n_{p_S}\right) \overline{M}_{pt_S}}{n_c + n_{p_S}} \qquad (16)$$

where n_c = the number of corrective maintenance actions in 1500 flight hours ($1500 \times \lambda m/1000{,}000$)

Other items are as previously defined.

5.1.3.2 3-M Data

As a comparison, the Navy 3-M data were used to determine the value of $\overline{M}$. Of the models covered in the 3-M data, UH-1D and AH-1G are the only ones of interest for this report. These data identify components by work unit code rather than part number; therefore, the analysis combines all similar components regardless of part number. The mean maintenance action time from the 3-M data analysis is presented in calendar hours, providing a comparison for monitored task times.

The maintenance actions were divided in two groups: "part replacements," both corrective and preventive (scheduled), and "on-aircraft" repairs (corrective). The part replacement items consider the remove-and-replace (installation of a like item) action times. The "on-aircraft" repairs are maintenance actions that are not "part replacements." The data did not include identifiable preventive maintenance actions other than scheduled replacements. "All Maintenance" is the two sets of data combined. The values for $\overline{M}_C$ for each component for each group of data were determined using the following equation:

$$\overline{M}_C = \frac{\sum_{i=1}^{n} M_i}{n} \qquad (17)$$

where $\overline{M}_C$ = mean maintenance action time for the component

M_i = maintenance time for ith action on the component

n = number of actions on the component

The subsystem $\overline{M}$ values were computed by using the following equation:

$$\overline{M}_{SS} = \frac{\sum_{j=1}^{m} r_j \overline{M}_{C_j}}{\sum_{j=1}^{m} r_j} \qquad (18)$$

where j = the jth component within the subsystem

r_j = maintenance rate of the jth component type

m = the number of different component types

The system $\overline{M}$ values were computed by using the following equation:

$$\overline{M}_{S} = \frac{\sum_{k=1}^{p} r_k \overline{M}_{SS_k}}{\sum_{k=1}^{p} r_k} \qquad (19)$$

where k = the kth subsystem within the system

r_k = the maintenance rate for the kth subsystem

p = the number of subsystems

The maintenance rates used were also extracted from the 3-M data.

5.2 MAINTAINABILITY INDEXES ANALYSIS RESULTS

5.2.1 Mean-Time-To-Repair (MTTR)

Table XII presents the MTTR values obtained by monitoring tail rotor maintenance. The task times are the same for all three models for most components. The UH-1D/H and UH-1C have the same task times except for the tail rotor drive shaft replacement (installation) time. This difference is caused by the difference in number of drive shafts: The UH-1C has five (one fin drive shaft and four tail boom drive shafts) and the UH-1D/H has six (one fin and five tail boom drive shafts).

TABLE XII. MEAN CORRECTIVE MAINTENANCE TIME (MTTR) GROUPED BY MAINTENANCE ACTION (Time Values Based on Monitored Data)

SUBSYSTEM Component Maintenance Action	MTTR (Hours, EMT)		
	UH-1D/H	UH-1C	AH-1G
TAIL ROTOR HUB & BLADE	0.4689	0.4490	0.5790
Remove	0.1668	0.1668	0.1668
Replace	1.1578	1.1578	1.3328
Track	0.0762	0.0762	0.0762
Grease	0.0800	0.0800	0.0800
TAIL ROTOR DRIVE	0.4290	0.5241	0.6863
42° Gearbox			
Remove	0.2983	0.2983	0.2983
Replace	0.8088	0.8088	0.8088
Service	0.1118	0.1118	0.1118
90° Gearbox			
Remove	0.4808	0.4808	0.5642
Replace	1.7593	1.7593	2.1084
Service	0.1482	0.1482	0.1482
Hanger Assembly			
Remove	0.1368	0.1368	0.1368
Replace	0.3947	0.3947	0.3947
Grease	0.6495	0.6495	0.6495
T/R Drive Shaft			
Remove	0.1145	0.1149	0.1149
Replace	0.3320	0.3329	0.3329
TAIL ROTOR CONTROL	0.2292	0.2205	0.2631
Chain			
Remove	0.1257	0.1257	0.1673
Replace	0.4047	0.4047	0.4625
Align (Rig)	0.5303	0.5303	0.6298
TOTAL TAIL ROTOR SYSTEM	0.3591	0.4224	0.4930

TABLE XII. (Cont'd)

SUBSYSTEM Component Maintenance Action	MTTR (Hours, EMT)		
	UH-1D/H	UH-1C	AH-1G
TAIL ROTOR CONTROL (Cont'd)			
Quill Assembly			
Remove	0.2268	0.2268	0.2685
Replace	0.8222	0.8222	0.9973
Control Tube			
Remove	0.2435	0.2435	0.2852
Replace	0.8390	0.8390	1.0140
Boot			
Remove	0.1017	0.1017	0.1017
Replace	0.3875	0.3875	0.3875
Slider			
Remove	0.1017	0.1017	0.1017
Replace	0.3875	0.3875	0.3875
Bearing Set			
Remove	0.0905	0.0905	0.0905
Replace	0.2907	0.2907	0.2907
Grease	0.0467	0.0467	0.0467
Crosshead			
Remove	0.0570	0.0570	0.0570
Replace	0.3138	0.3138	0.3138
Pitch Change Link			
Remove	0.0650	0.0650	0.0650
Replace	0.1938	0.1938	0.1938

The fin drive shaft requires a little more task time than the others. The time value for this part is weighted more heavily for the aircraft with fewer drive shafts, thus resulting in higher overall time for UH-1C drive shafts. The AH-1G and UH-1C drive shafts require the same amount of maintenance time.

There is a difference in average task times between the AH-1G and UH-1D H C for some maintenance actions. The AH-1G sometimes requires, in addition to the other task elements, the removal of one or both of the tail fin fairings. The UH-1 models do not have fin fairings covering the 90-degree gearbox and control quill, tube, and chain.

5.2.2 Mean Preventive Maintenance Action Time ($\overline{M}_{pt}$)

Tables XIII through XIX present the $\overline{M}_{pt}$ grouped by model and subsystem. Component tables are presented only if there is more than one type of action per component. The average maintenance time computed from the data obtained during the monitoring of the tail rotor maintenance and the number of times each action is repeated in a 1500-hour interval are presented. Notice that scheduled actions may have time values different from the unscheduled maintenance actions presented in Table XII. This is because a scheduled removal of the 90-degree gearbox, for instance, requires less time than an unscheduled removal because opening of access doors and removal of controls to gain access to the gearbox have already been accomplished as a part of the eleventh 100-hour inspection.

5.2.3 Mean Preventive and Corrective Action Time ($\overline{M}$)

Table XX presents the subsystem and system $\overline{M}$ for all the models, calculated using the MTTR and $\overline{M}_{pt}$ obtained from monitored task time data.

Table XXI presents $\overline{M}$ in calendar hours elapsed maintenance time EMT obtained from 3-M data. In Table XXII, the system and subsystem values under "All Maintenance" are compared to the $\overline{M}$ values presented in Table XX.

The difference between the values obtained from the two data sources is probably due to the reporting methods. The monitored data includes only actual "touch time." The 3-M data probably represents touch time and other actions required by maintenance men to accomplish a task; that is, preparing an area for removed parts, getting tools, doing paperwork in connection with the task, and even coffee breaks, should they occur in the midst of a task. The last item is probably included in the time reported due to a requirement that every

TABLE XIII. MEAN PREVENTIVE MAINTENANCE ACTION TIME ($\overline{M}_{pt}$) FOR THE TAIL ROTOR SYSTEM (Expressed in Hours EMT)

Maintenance Action	UH-1D/H		UH-1C		AH-1G	
	No.*	M_{pt}	No.*	M_{pt}	No.*	M_{pt}
Inspect	240.00	0.1924	240.00	0.1924	240.00	0.1924
Remove	17.36	0.1699	17.36	0.1699	17.36	0.1808
Replace	17.36	0.6078	17.36	0.6078	17.36	0.7863
Align	120.00	0.2916	120.00	0.2916	120.00	0.3412
Track	60.00	0.0762	60.00	0.0762	60.00	0.0762
Grease	46.73	0.1248	43.73	0.1178	43.73	0.1178
Service	30.00	0.1174	30.00	0.1174	30.00	0.1174
All Actions	531.45	0.2040	528.45	0.2042	528.45	0.2215

* The number of actions occurring in a 1500-flight-hour interval

TABLE XIV. MEAN PREVENTIVE MAINTENANCE ACTION TIME ($\overline{M}_{pt}$) FOR THE TAIL ROTOR HUB AND BLADE (Expressed in Hours EMT)

Maintenance Action	UH-1D/H		UH-1C		AH-1G	
	No.*	M_{pt}	No.*	M_{pt}	No.*	M_{pt}
Inspect	60.00	0.0834	60.00	0.0834	60.00	0.0834
Remove	15.00	0.1669	15.00	0.1669	15.00	0.1669
Replace	15.00	0.6155	15.00	0.6155	15.00	0.7905
Align	60.00	0.0527	60.00	0.0527	60.00	0.0527
Track	60.00	0.0762	60.00	0.0762	60.00	0.0762
Grease	15.00	0.0800	15.00	0.0800	15.00	0.0800
Service	-	-	-	-	-	-
All Actions	225.00	0.1140	225.00	0.1140	225.00	0.1257

* The number of actions occurring in a 1500-flight-hour interval

TABLE XV. MEAN PREVENTIVE MAINTENANCE ACTION TIME ($\bar{M}_{pt}$) FOR THE TAIL ROTOR DRIVE SUBSYSTEM (Expressed in Hours EMT)						
Maintenance Action	UH-1D/H		UH-1C		AH-1G	
	No.*	M_{pt}	No.*	M_{pt}	No.*	M_{pt}
Inspect	60.00	0.0834	60.00	0.0834	60.00	0.0834
Remove	2.36	0.2452	2.36	0.2452	2.36	0.2692
Replace	2.36	0.5591	2.36	0.5591	2.36	0.7602
Align	-	-	-	-	-	-
Track	-	-	-	-	-	-
Grease	16.73	0.2410	13.73	0.2442	13.73	0.2442
Service	30.00	0.1147	30.00	0.1147	30.00	0.1147
All Actions	111.45	0.1290	108.45	0.1262	108.45	0.1310

* The number of actions occurring in a 1500-flight-hour interval

TABLE XVI. MEAN PREVENTIVE MAINTENANCE ACTION TIME ($\bar{M}_{pt}$) FOR THE 90-DEGREE GEARBOX (Expressed in Hours EMT)						
Maintenance Action	UH-1D/H		UH-1C		AH-1G	
	No.*	M_{pt}	No.*	M_{pt}	No.*	M_{pt}
Inspect	**		**		**	
Remove	1.36	0.3012	1.36	0.3012	1.36	0.3429
Replace	1.36	0.6986	1.36	0.6986	1.36	1.0479
Align	-	-	-	-	-	-
Track	-	-	-	-	-	-
Grease	2.73	0.1657	2.73	0.1657	2.73	0.1657
Service	15.00	0.1482	15.00	0.1482	15.00	0.1482
All Actions	20.45	0.1974	20.45	0.1974	20.45	0.2232

* The number of actions occurring in a 1500-flight-hour interval

** Included in Tail Rotor Drive Subsystem Inspection

TABLE XVII. MEAN PREVENTIVE MAINTENANCE ACTION TIME ($\overline{M}_{pt}$) FOR THE 42-DEGREE GEARBOX (Expressed in Hours EMT)

Maintenance Action	UH-1D/H		UH-1C		AH-1G	
	No.*	M_{pt}	No.*	M_{pt}	No.*	M_{pt}
Inspect	**		**		**	
Remove	1.00	0.1687	1.00	0.1687	1.00	0.1687
Replace	1.00	0.3691	1.00	0.3691	1.00	0.3691
Align	-	-	-	-	-	-
Track	-	-	-	-	-	-
Grease	2.00	0.4314	2.00	0.4314	2.00	0.4314
Service	15.00	0.0813	15.00	0.0813	15.00	0.0813
All Actions	19.00	0.1379	19.00	0.1379	19.00	0.1379

* The number of actions occurring in a 1500-flight-hour interval

** Included in Tail Rotor Drive Subsystem Inspection

TABLE XVIII. MEAN PREVENTIVE MAINTENANCE ACTION TIME ($\overline{M}_{pt}$) FOR THE TAIL ROTOR HANGER ASSEMBLIES (Expressed in Hours EMT)

Maintenance Action	UH-1D/H		UH-1C		AH-1G	
	No.*	M_{pt}	No.*	M_{pt}	No.*	M_{pt}
Inspect	**		**		**	
Remove	-	-	-	-	-	-
Replace	-	-	-	-	-	-
Align	-	-	-	-	-	-
Track	-	-	-	-	-	-
Grease	12.00	0.2265	9.00	0.2265	9.00	0.2265
Service	-	-	-	-	-	-
All Actions	12.00	0.2265	9.00	0.2265	9.00	0.2265

* The number of actions occurring in a 1500-flight-hour interval

** Included in Tail Rotor Drive Subsystem Inspection

TABLE XIX. MEAN PREVENTIVE MAINTENANCE ACTION TIME ($\overline{M}_{pt}$) FOR THE TAIL ROTOR CONTROL SUBSYSTEM (Expressed in Hours EMT)

Maintenance Action	UH-1D/H		UH-1C		AH-1G	
	No.*	M_{pt}	No.*	M_{pt}	No.*	M_{pt}
Inspect	60.00	0.2402	60.00	0.2402	60.00	0.2402
Remove	-	-	-	-	-	-
Replace	-	-	-	-	-	-
Align	60.00	0.5304	60.00	0.5304	60.00	0.6300
Track	-	-	-	-	-	-
Grease	15.00	0.0400	15.00	0.0400	15.00	0.0400
Service	-	-	-	-	-	-
All Actions	135.00	0.3469	135.00	0.3469	135.00	0.3911

* The number of actions occurring in a 1500-flight-hour interval

TABLE XX. MEAN MAINTENANCE ACTION TIME ($\overline{M}$) FOR THE TAIL ROTOR SYSTEM BASED ON MONITORED DATA (Expressed in Hours EMT)

Model	Subsystem	Corrective		Preventive		All	
		No.*	MTTR	No.*	$\overline{M}_{pt}$	No.*	$\overline{M}$
UH-1D/H	T/R Hub and Blade	3.386	0.4689	225.00	0.1140	228.386	0.1193
	T/R Drive	6.400	0.4290	111.45	0.1290	117.850	0.1453
	T/R Control	6.311	0.2292	135.00	0.3469	141.311	0.3416
	TOTAL T/R SYSTEM	16.097	0.3591	531.45	0.2040	547.547	0.2086
UH-1C	T/R Hub and Blade	8.753	0.4490	225.00	0.1140	233.753	0.1265
	T/R Drive	5.625	0.5241	108.45	0.1262	114.075	0.1458
	T/R Control	3.989	0.2205	135.00	0.3469	138.989	0.3433
	TOTAL T/R SYSTEM	18.367	0.4224	528.45	0.2042	546.817	0.2115
AH-1G	T/R Hub and Blade	3.770	0.579[illegible]	225.00	0.1257	228.770	0.1332
	T/R Drive	8.901	0.6863	108.45	0.1310	117.351	0.1731
	T/R Control	8.898	0.2631	135.00	0.3911	143.898	0.3832
	TOTAL T/R SYSTEM	21.569	0.4930	528.45	0.2215	550.019	0.2321

* Number of maintenance actions in 1500 flight hours

TABLE XXI. MEAN MAINTENANCE ACTION TIME ($\overline{M}$) FOR THE TAIL ROTOR SYSTEM FROM 3-M DATA (Expressed in Hours EMT)

SUBSYSTEM Component	All Maintenance		Part Replacement		On A/C Repair	
	AH-1G	UH-1D	AH-1G	UH-1D	AH-1G	UH-1D
T/R HUB & BLADE	1.66	0.96	2.24	1.81	1.21	0.67
T/R Hub	1.66	0.84	2.67	2.21	0.79	0.41
T/R Blade	1.86	1.07	1.89	1.27	1.77	0.93
Other	1.57	1.36	1.66	0.79	1.54	1.47
T/R DRIVE	0.93	1.69	1.06	2.32	0.69	1.70
T/R Drive Shaft	0.77	1.51	0.78	2.37	0.75	1.26
Hanger Assembly	0.63	0.98	0.68	1.41	0.43	0.69
42° Gearbox	1.13	1.97	1.59	2.68	0.69	1.70
90° Gearbox	1.80	2.33	2.83	3.58	0.86	2.02
Other	0.91	1.36	0.93	1.33	0.92	2.31
T/R CONTROL	1.20	1.30	1.38	1.98	1.08	1.03
Control Quill*	2.08	1.90	3.50	4.00	0.95	1.07
Control Tube	3.00	1.75	4.50	1.75	1.02	-
Pitch Control Mechanism**	1.27	1.58	1.10	1.33	1.47	1.51
Chain	0.91	2.55	0.83	3.40	1.25	1.71
Pitch Change Link	0.99	1.29	1.25	2.09	0.88	1.03
Crosshead	1.32	0.98	1.30	0.86	1.33	1.45
TOTAL T/R SYSTEM	1.17	1.25	1.34	2.01	0.94	1.55

*Includes sprocket wheel

**Includes cone set, static stop, nut, boot, slider, plate, crosshead bearing

minute of the maintenance personnel's work day must be charged to a maintenance task.

TABLE XXII. COMPARISON OF $\bar{M}$ VALUES

Subsystem	Monitored Data			3-M Data	
	UH-1D/H	UH-1C	AH-1G	UH-1D	AH-1G
Hub and Blade	0.1193	0.1265	0.1332	0.96	1.66
Drive Subsystem	0.1453	0.1458	0.1731	1.69	0.93
Control Subsystem	0.3416	0.3433	0.3832	1.30	1.20
TOTAL T/R SYSTEM	0.2086	0.2115	0.2321	1.25	1.17

6. MEAN-TIME-TO-REMOVAL (MTR) AND MEAN-TIME-BETWEEN-REMOVAL (MTBR) ANALYSES

6.1 MTR AND MTBR ANALYSIS APPROACH

6.1.1 Computing MTR

MTR of an item is the average of the total operating time (measured in flight hours) of the items removed. It is computed by summing the total time t_i on each item and dividing the result by the number of items n removed, as shown in the following equation:

$$MTR = \frac{\sum_{i=1}^{n} t_i}{n} \tag{20}$$

This equation is used to compute the MTR for the items removed for all causes of removal as well as for the items removed for each specific failure cause. While the MTR computed for items removed for all causes and for each of the subgroups of removal reasons (i.e., unscheduled maintenance, material failures, external failure causes, no failure causes, scheduled maintenance) are reasonably meaningful, the MTR values for a small number of items removed for failure modes which seldom occur are not really significant.

Another factor that is important when conducting MTR analysis is that early component analyses of a new production fleet using the above equation will give results which are very misleading. Obviously, if the fleet has accrued only, say, 300 flight hours per aircraft, the few components removed will have an MTR of 300 hours or less while the components remaining on the aircraft and which continue to acquire time may well have operating times greater than the components removed. In this situation it is preferable to estimate the MTBF or MTBR to obtain values that are significant for the component.

This tail rotor system analysis is for components of mature aircraft. The MTR equation has been used to obtain the values presented in Appendix II.

6.1.2 Computing MTBR

Mean time between removals (MTBR) is the average interval in hours between maintenance actions resulting in the removal of an item from a fleet of aircraft. It is computed using the following equation:

$$\text{MTBR} = \frac{k \sum_{j=1}^{m} T_j}{n} \tag{21}$$

where $\sum_{j=1}^{m} T_j$ = the total flight hours on a fleet of m aircraft

T_j = the time on the jth aircraft

k = the number of items installed per aircraft

n = the number of reported removals in the fleet

This equation is similar to mean time between failures (MTBF) equation (1), except n in this case is number of removals while n in the MTBF equation is number of failures.

There are several significant factors to be recognized in MTBR analysis.

a. The MTBR for an item for all removal causes may be close to, although it should be larger than, its MTR for all causes. This is because the total fleet time will be equal to the total hours on the items removed PLUS the total time on the items installed and still operating. It is only at some theoretical point in time where all the items have been removed without replacement and the fleet is shut down that the MTR and MTBR for all causes will become equal.

b. The item's MTBR for all subgroups of removal reasons will be greater than the item's MTBR for all removal causes. Obviously, since the number of removals decreases for the subgroups of removal reasons while the fleet time stays the same, the resulting MTBR will be larger.

c. The MTBR for items removed for causes that seldom occur can be very large. Here the significance in

the value is that it permits identification of a removal reason that is probably not cost effective to correct. Conversely, the removal causes with the lower MTBR valves are those for which product improvement may be justified.

While the overhaul and DA form 2410 removal history data provide time for the items removed, it is not necessarily a complete history of the item removals. Also, as discussed in a above, the total hours in the component removal data are less than the hours on all the items since the items in the aircraft are also accruing time. To compensate for this, the MTBR equation can be modified as follows:

$$MTBR = \frac{T_f}{n'} \tag{22}$$

where T_f = an adjusted total time for the items that have been removed and that are installed

n' = an adjusted number of items removed

where

$$T_f = \sum_{i=1}^{n} t_i + MTR_T \times km \tag{23}$$

where $\sum_{i=1}^{n} t_i$ = the total time on the items n removed for all causes

MTR_T = the item's mean time to removal for all causes

m = the estimated number of aircraft in the fleet

k = number of items installed per aircraft

and where $n' = n + km$. (24)

This modification assumes that at a specific point in time the items installed on the operating aircraft will eventually be removed and that these items at removal will have an MTR equivalent to that already observed on the items previously removed. This assumption becomes reasonable only after the aircraft fleet becomes mature, that is, after it has completed a sufficient portion of its life cycle so that the component MTR's have essentially reached their maximum and become level.

By performing the algebra associated with these modifications, the equation reduces to

$$\text{MTBR} = \frac{\sum_{i=1}^{n} t_i}{n} \tag{25}$$

This is the same as the MTR equation (20) for "All Cause" removals. However, in Section 6.1.2 the analysis factor a states that the MTBR values for "All Cause" removals are larger than the MTR values for "All Cause" removals until the fleet essentially completes its life cycle. This means that MTR_T in equation (23) should be somewhat larger than that previously observed on the items already replaced. But the magnitude of this difference cannot be estimated since it will vary with the maturity of the aircraft fleet. The UH-1C/D/H and AH-1G aircraft are sufficiently mature to expect this difference to be minimal. Therefore, in the MTR/MTBR component analyses in Appendix II, the total component times used to compute the "All Cause" removal MTR values and to compute the MTBR values are equal and the resulting "All Cause" removal MTR and MTBR values are shown as equal.

The following equation was used to compute the component MTBR for the subgroups of removal reasons:

$$\text{MTBR}_h = \frac{\sum_{i=1}^{n} t_i}{n_h} \tag{26}$$

where MTBR_h = the mean-time-between-removals of the item for subgroup h removal cause

n_h = the number of items removed for subgroup h removal cause

$\sum_{i=1}^{n} t_i$ = the total time on the items n removed for all causes

6.1.3 Sources of Data

Two data sources were used for the MTR/MTBR analyses:

- SAV Form 634 data - disassembly inspection summary reports of UH-1C/D/H and AH-1G assemblies overhauled or received for overhaul and scrapped at BHC

- Army Reliability and Maintainability Maintenance Improvement Techniques (RAMMIT) Major Item Removal Frequency (MIRF) reports [4, 5, 6] of DA form 2410 component removal and installation records

To obtain a representative sample from the first source, the following technique was used. Only those assemblies which had serial numbers the same as those originally installed on aircraft that had accrued more than 1100 hours (the usual time between overhauls (TBO)) were included in the sample. This provides the most correct ratio of premature removals to TBO removals from the data source. Only the 42- and 90-degree gearbox assemblies were analyzed from this data source. The data used were for the period from initial delivery of the production aircraft through 1970. Since both the tail rotor hub and tail rotor blades are retirement items, they did not appear in the overhaul data. The drive-shaft hanger bearing assemblies which are overhauled are "on condition" items (have no assigned TBO) and are installed three (UH-1C/AH-1G) or four (UH-1D/H) per aircraft. Although the overhaul data contained a large number of assemblies, it was not possible to determine an adequate sample from this source.

The tail rotor system components that were selected from the second data source were those which had at least 100 removal records. The MIRF reports were available only on Model UH-1D, UH-1H, and AH-1G components. The reports used contained removal data for the interval from 1 January 1964 through 30 June 1971 for the UH-1D and through 31 December 1971 for the UH-1H and AH-1G.

6.1.4 Formatting the Analysis

For the purpose of presenting the mean-time-to-removal (MTR) and mean-time-between-removal (MTBR) analyses, the individual removal reasons were combined to form the following groups of reason for removal classifications:

- All Causes
    - Unscheduled Maintenance/Failure
        - Material (Inherent Failures)
        - External and Induced Failures
    - Inspection
    - Scheduled Overhaul (TBO)

- Other Removal Reasons as Applicable
  - No Defect
  - Other Scheduled Maintenance
  - Unknown

The material failures category consists of those reasons that are inherent in, or are thought to be the fault of, the item under consideration, e.g., bearing failure, oil leakage, etc.

The external failures category consists of those reasons that are not the fault of the item under consideration but were induced or caused by some external agent, e.g., foreign object damage, combat damage, etc.

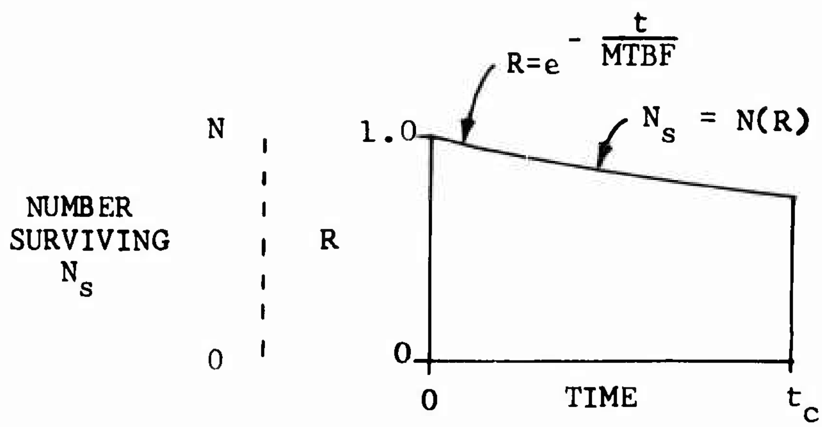
The unknown category includes those records where reasons for removal are unstated or reasons that are inconsistent with the item being removed; e.g., fuse blown, poor focus, etc., for removal of a tail rotor blade.

6.1.5 Grouping the Data

With such a large number of failure codes to select from, it was apparent when reviewing the MIRF data that several codes used had the same meaning for the component being reported: e.g., 381- leaking and 307- oil leak; 008- noisy and 150- chattering; and 670- unbalanced and 690- vibration excessive. As a result, to make the analyses more meaningful, records of removals with codes where only a small number of components were reported were grouped with those with essentially the same failure mode where a large number of components were reported.

6.1.6 Estimating MTBR From Component MTBF

If the failure rate of a component is constant, i. e., $R = \exp - \lambda t$ (where $\lambda = 1/\text{MTBF}$), if the component is life limited or has an assigned TBO, and if the mean time between removals (MTBR_e) to be estimated considers only failure cause and time change removals, the equation for the MTBR_e can be obtained for a quantity of components N for which an MTBF is known by integrating the area under the reliability curve between the limits of zero time and the assigned time change t_c.



The following developes the equation to obtain $MTBR_e$ where N is the original quantity of components.

$$N \times MTBR_e = N \int_0^{t_c} e^{-\frac{t}{MTBF}} dt$$

$$MTBR_e = \int_0^{t_c} e^{-\frac{t}{MTBF}} dt$$

$$= MTBF \left[- e^{-\frac{t}{MTBF}} \right]_0^{t_c}$$

$$= MTBF \left[- e^{-\frac{t_c}{MTBF}} - \left(- e^{-\frac{0}{MTBF}} \right) \right]$$

$$= MTBF \left[1 - e^{-\frac{t_c}{MTBF}} \right] \tag{27}$$

Figure 7 shows the relationship between MTBF and $MTBR_e$ for components with time changes of 1100, 1500, 2500, and 5000 hours based on equation (27).

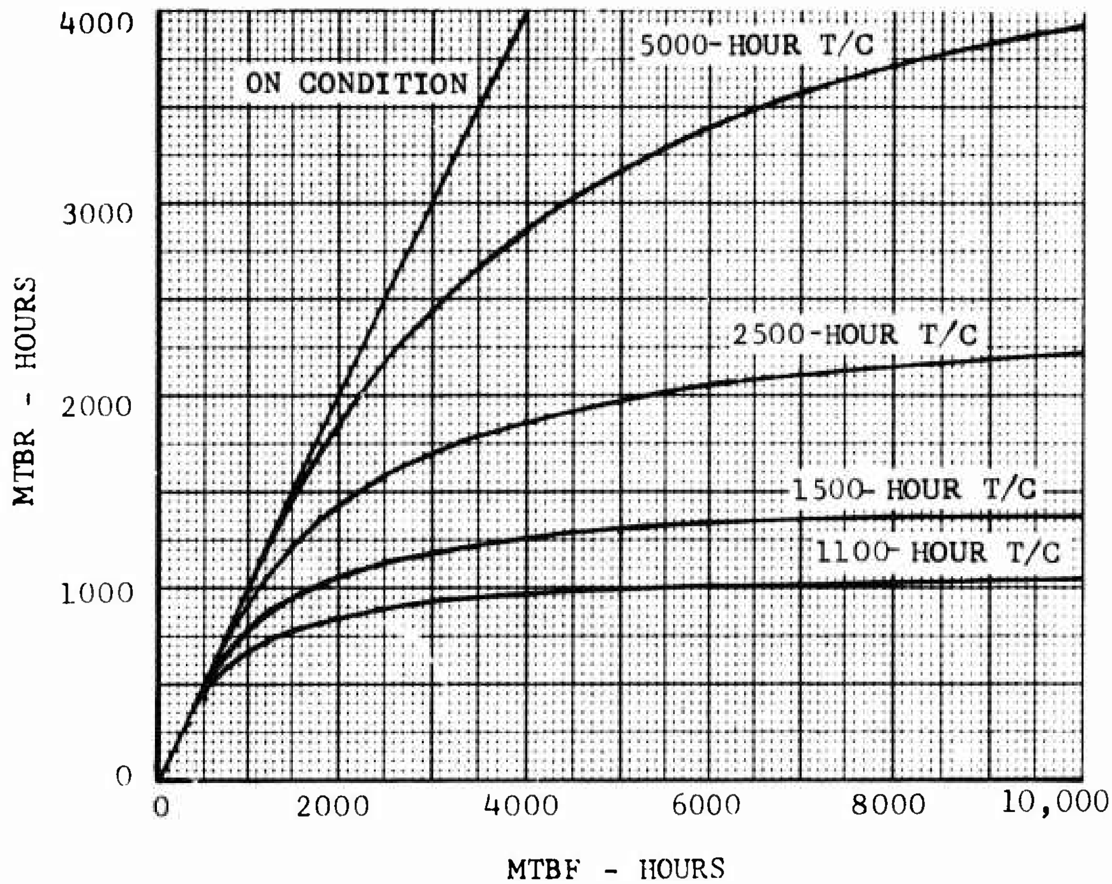


Figure 7. MTBF Versus MTBR for 1100-, 1500-, 2500-, and 5000-Hour Time Change Components and On-Condition Components.

The $MTBR_e$ values were estimated from the MIRF data analyses for each component by equating the MTBF to the component MTBR shown in Tables LXXVII through CII in Appendix II for "Unscheduled Maintenance" removals and time change t_c to 1100 hours for the hubs, blades and 90-degree gearboxes, 1500 hours for the 42-degree gearboxes, and 5000 hours (approximate aircraft life) for the hanger assemblies. In computing $MTBR_e$, the no-failure cause removal components are considered to have been reinstalled and permitted to operate until they are subsequently removed for failure or time change.

Figures 8 and 9, developed using the reliability and $MTBR_e$ equations, show the percentage of the limited-life assemblies that can be expected to achieve time change versus their MTBF and MTBR values.

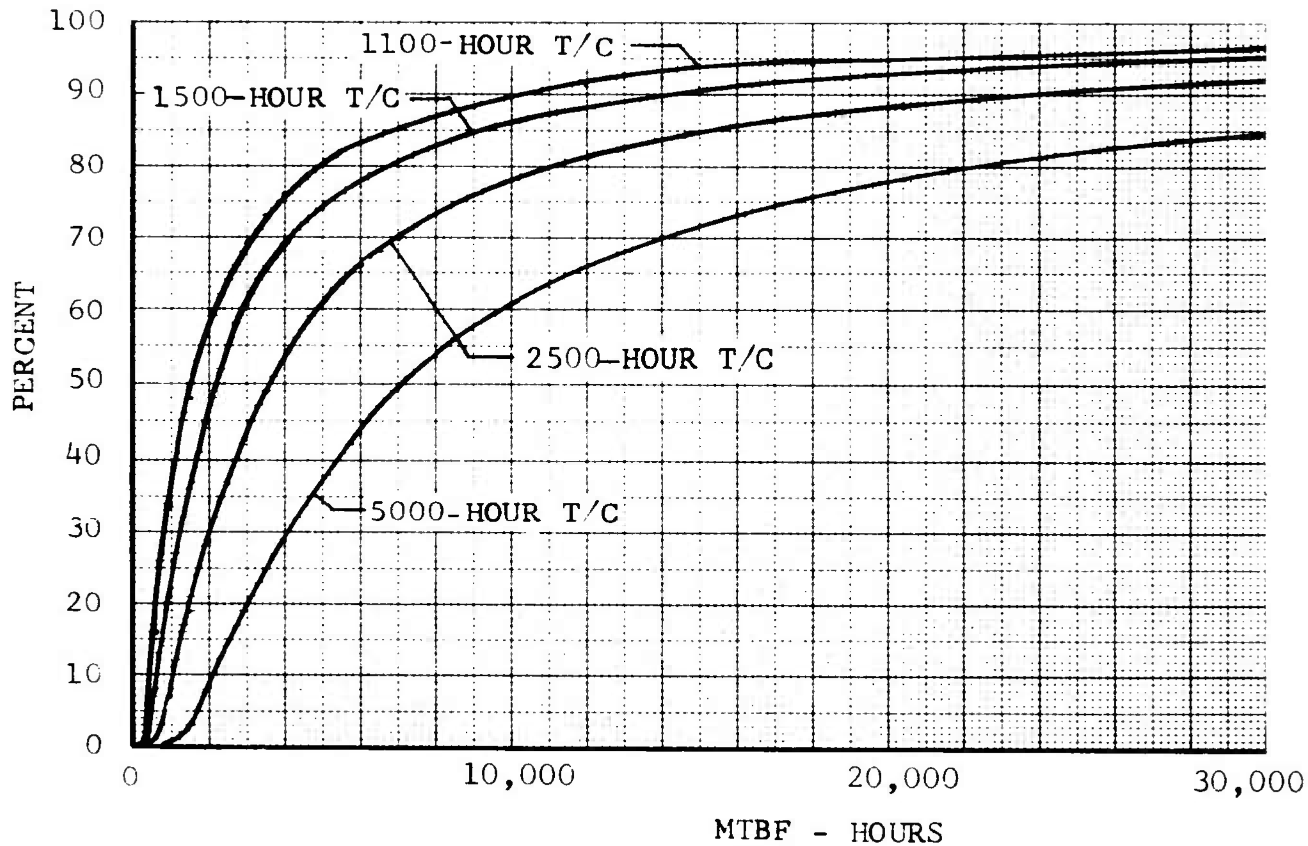


Figure 8. Percentage of the Components That Will Survive to Time Change Versus MTBF.

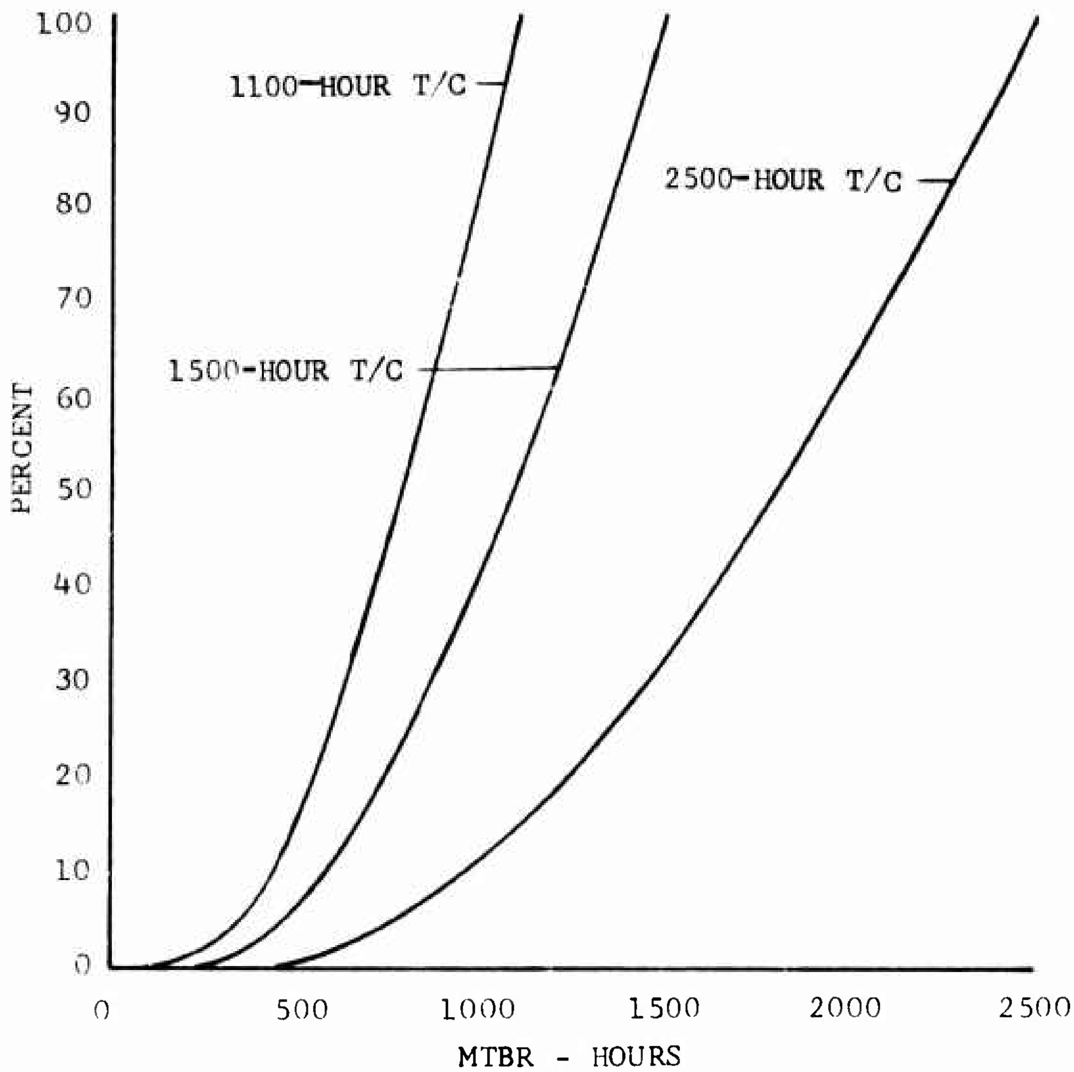


Figure 9. Percentage of the Components That Will Survive to Time Change Versus Their MTBR.

6.1.7 Other Variations in MTBR Estimating

Modifications of the $MTBR_e$ equation (27) can be used to project the MTBR where a repairable fraction of the TBO or limited-life components is repaired, reinstalled (not necessarily on the same aircraft), and later removed for failure or time change causes. This failure and repair process may occur several times to a component before it is sent to overhaul or is retired. Appendix VI shows the equations and a set of examples for this estimation.

6.2 MTR AND MTBR ANALYSIS RESULTS

6.2.1 BHC Overhaul Data

Table XXIII summarizes the results of the MTR and MTBR analysis of the 42- and 90-degree gearbox data on assemblies processed for overhaul at BHC. The more detailed results of the analysis are shown in the first sixteen tables in Appendix II. Table XXIII shows that the MTR and MTBR values for the AH-1G assemblies are consistently lower than those of the UH-1 models. The MTR for the later dash-numbered assemblies is higher than for the earlier assemblies both for "All Causes" of removal and for "Unscheduled Maintenance" ("Failure") causes. However, even though the MTBR values for the same later dash-numbered assemblies were higher than for the earlier assemblies for "All Causes" of removal, they were lower in the later assemblies for "Failure" causes of removal. The number of assemblies removed for these causes (presented in Appendix II) shows that while from 19 to 24 percent of the earlier assemblies were removed for failures, 32 to 42 percent of the later dash-numbered assemblies were so removed although they had a higher average time. Explanation of probable cause for the increased failure percentage is given in 6.2.2.1 Basic MTR/MTBR Analysis.

The significant failure modes for the two types of gearboxes were:

a. Material Failures (MF) - 63 percent of the Unscheduled Maintenance removals

- Leakage - 60 percent of the MF removals
- Metal Particles - 13 percent of the MF removals
- Excessive Wear - 5 percent of the MF removals
- Internal Failure - 5 percent of the MF removals

b. Externally Caused Failures (ECF) - 37 percent of the Unscheduled Maintenance removals

- Sudden Stoppage - 48 percent of the ECF removals
- Crash - 17 percent of the ECF removals
- Hard Landing/Overstressed - 11 percent of the ECF removals

These results were generally consistent with the results of the RAMMIT MIRF report data discussed below.

TABLE XXIII. SUMMARY OF MTR/MTBR ANALYSIS OF BHC COMPONENT OVERHAUL DATA

Component Part Number	Model	Mean Time To Removal				Mean Time Between Removals				Total Part Hours
		All Causes	Failure Causes	Time Change	Other Reasons	All Causes	Failure Causes	Time Change	Other Reasons	
42° Gearbox										
204-040-003-23	UH-1C	936	715	1391	350	936	2247	2247	5617	11,234
204-040-003-23	UH-1D	955	619	1149	643	955	5440	1529	4774	233,939
204-040-003-23	C/D	954	629	1157	632	954	5108	1552	4807	245,173
204-040-003-37	UH-1C	1116	917	1430	791	1116	3128	2548	5432	206,412
204-040-003-37	UH-1D	1038	735	1439	779	1038	2783	2487	4948	489,883
204-040-003-37	UH-1H	1000	674	1467	710	1000	2268	2474	6459	381,059
204-040-003-37	AH-1G	681	556	1456	306	681	1178	3404	3063	30,633
204-040-003-37	CDHG	1023	728	1448	739	1023	2541	2512	5379	1,107,987
All 42s	CDHG	1010	718	1371	737	1010	2796	2259	5265	2,706,320
90° Gearbox										
204-040-012-7	UH-1C	928	719	1067	1100	928	2253	1972	7887	15,773
204-040-012-7	UH-1D	868	580	1092	646	868	3890	1635	3537	194,518
204-040-012-7	C/D	873	597	1091	662	873	3689	1656	3689	210,291
204-040-012-13	UH-1C	878	674	1085	690	878	2508	1795	5448	157,988
204-040-012-13	UH-1D	929	677	1094	702	929	3512	1558	6794	414,413
204-040-012-13	UH-1H	861	675	1097	568	861	2393	1792	5375	327,902
204-040-012-13	AH-1G	712	429	1130	448	712	1498	1779	5694	28,469
204-040-012-13	CDHG	887	662	1094	639	887	2756	1680	5954	928,772
All 90s	CDHG	884	652	1094	645	884	2891	1675	5348	2,278,126

6.2.2 RAMMIT MIRF Report Data

6.2.2.1 Basic MTR/MTBR Analysis

Table XXIV summarizes the results of MTR and MTBR analysis of the RAMMIT MIRF report data on fourteen assemblies installed on one or more of the three aircraft models, UH-1D, UH-1H and AH-1G. The more detailed analyses are contained in Appendix II. In this analysis, as was previously shown in the overhaul data analysis, the MTR/MTBR values for all causes of removal were consistently lower for the AH-1G than for the UH-1D/H. However, the later dash-numbered assemblies showed higher MTR/MTBR values for all causes of removal for only some of the components. (For the components listed, where the first 9 numbers of a part number are the same, the larger number in the final dash number designates the newer designs. Also the -801 tail rotor hub assemblies are more recent designs than the -701 hubs.)

Table XXV compares the number of failure-caused removals as a percentage of total removals for the earlier and later assemblies. Similarly, it also compares the number of material-failure-caused removals as a percentage of total removals for the same assemblies. The MTR/MTBR values for these removals are also presented. No consistent trend is observable.

Since an increase MTR/MTBR for the later (improved) assemblies is the trend one would expect to see in the analyses and since the characteristics of most changes in this type of equipment are such that the later assemblies are at least as good as the earlier ones, other reasons for explaining the results of the analyses must be identified. There are two factors that impact on the later 42- and 90-degree gearboxes. First, the later assemblies have a chip detector installed which alerts maintenance personnel to a metal-chip contaminated oil condition. This results in either gearbox replacement at an earlier time than would have been the case on the earlier assemblies, or an oil change. The most frequent action is the oil change. This change reduces the accelerated wear and secondary damage that can be caused by the abrasive lubricant. The overall result is that the later assemblies could attain either a shorter or longer installed time depending on which action predominated.

The second factor is that these data cover the initial installations of the components on new aircraft. As such, the earlier dash-numbered assemblies were on the earlier fiscal year aircraft during the period when their initial utilization was in the United States, prior to their being deployed in Vietnam. The later aircraft with the later assemblies were primarily deployed directly to Vietnam shortly after delivery. The

TABLE XXIV. SUMMARY OF MTR/MTBR ANALYSIS OF RAMMIT MIRF DATA

Component Part Number	Model	Mean Time To Removal				Mean Time Between Removals				Total Part Hours
		All Causes	Failure Causes	Time Change	Other Reasons	All Causes	Failure Causes	Time Change	Other Reasons	
T/R Hub										
204-011-701-11	UH-1D	389	440	669	330	389	1012	7593	690	75,929
204-011-701-19	UH-1D	151	197	299	138	151	1558	3432	176	288,281
204-011-801-5	UH-1D	318	408	93	281	318	1040	34311	464	34,311
204-011-801-9	UH-1D	238	285	590	204	238	612	29682	396	59,365
204-011-701-19	UH-1H	157	256	334	139	157	1850	3894	179	482,853
204-011-801-5	UH-1H	264	315	319	239	264	852	12497	395	112,469
204-011-801-9	UH-1H	308	331	186	313	308	746	3863	608	768,752
All D/H Hubs	D/H	215	309	267	184	215	1004	4247	293	1,821,960
209-011-701-3	AH-1G	126	145	205	118	126	632	5422	161	130,118
204-011-801-3	AH-1G	235	271	442	205	235	535	68534	421	205,602
All G Hubs	AH-1G	176	227	231	151	176	569	12434	259	335,720
All Hubs	D/H/G	208	289	264	179	208	898	4732	287	2,157,680
T/R Blades										
204-011-702-15	UH-1D	354	345	871	320	354	1335	7191	516	668,769
204-011-702-15	UH-1H	319	347	849	279	319	871	11812	526	2,516,138
All D/H Blades	D/H	326	347	853	287	326	940	10408	523	3,184,907
204-011-702-17	AH-1G	221	239	674	201	221	638	15069	346	678,086
All Blades	D/H/G	301	321	832	266	301	868	11006	480	3,862,993
42° Gearboxes										
204-040-003-23	UH-1D	717	526	1118	619	717	1637	2580	2527	371,489
204-040-003-37	UH-1D	757	571	1369	682	757	1575	4037	2285	1,210,994
204-040-003-37	UH-1H	656	543	1410	687	656	1076	8445	2096	1,739,708
All D/H 42s	D/H	696	550	1327	679	696	1271	5111	2204	3,322,191
204-040-003-37	AH-1G	572	497	1384	585	572	924	10948	1739	558,336
All 42s	D/H/G	675	540	1331	662	675	1206	5536	2123	3,880,527

TABLE XXIV. (Cont'd)

Component Part Number	Model	Mean Time To Removal				Mean Time Between Removals				Total Part Hours
		All Causes	Failure Causes	Time Change	Other Reasons	All Causes	Failure Causes	Time Change	Other Reasons	
90° Gearboxes										
204-040-012-7	UH-1D	729	543	1088	591	729	1791	2303	2638	145,076
204-040-012-13	UH-1D	697	474	1054	651	697	1624	2294	2618	1,094,370
204-040-012-13	UH-1H	614	481	1073	634	614	1146	4368	1894	1,725,444
All D/H 90's	D/H	647	481	1064	637	647	1311	3171	2142	2,964,890
204-040-012-13	AH-1G	550	432	1059	597	550	982	5580	1613	474,303
All 90's	D/H/G	632	473	1064	630	632	1253	3372	2050	3,439,193
D/S Hanger Assembly										
204-040-600-7	UH-1D	373	143	1011	565	373	645	3225	1216	1,938,084
204-040-600-9	UH-1D	430	414	571	457	430	665	59371	1245	1,662,284
204-040-600-7	UH-1H	560	625	405	451	560	889	89444	1542	447,222
204-040-600-9	UH-1H	515	506	585	540	515	709	261192	1899	5,485,034
All D/H Hangers	D/H	465	414	974	524	465	693	14554	1561	9,532,624
204-040-600-9	AH-1G	435	430	376	445	435	652	273639	1316	1,094,556
All Hangers	D/H/G	462	416	970	514	462	689	16126	1531	10,627,180

TABLE XXV. COMPARISON OF RAMMIT MIRF ANALYSIS VALUES OF EARLY AND LATER COMPONENTS

Component	Model	Part Number	All Failure Causes			Material Failure Causes		
			Percent Total Removals	MTR	MTBR	Percent Total Removals	MTR	MTBR
Tail Rotor Hub	UH-1D	204-011-701-11	38	440	1012	26	482	1519
		204-011-701-19	10	197	1558	5	238	2854
		204-011-801-5	31	408	1040	24	433	1320
		204-011-801-9	39	285	612	30	334	802
	UH-1H	204-011-701-19	8	256	1850	4	286	3603
		204-011-801-5	31	315	852	21	370	1264
		204-011-801-9	41	331	746	29	359	1050
	AH-1G	209-011-701-3	20	145	632	6	203	2002
		204-011-801-3	44	271	535	32	303	740
42° Gearbox	UH-1D	204-040-003-23	44	526	1637	24	526	2692
		204-040-003-37	48	571	1575	32	608	2333
90° Gearbox	UH-1D	204-040-012-7	41	543	1791	25	583	2961
		204-040-012-13	43	474	1624	29	505	2405
Hanger Assembly	UH-1D	204-040-600-7	57	143	645	46	580	814
		204-040-600-9	65	414	665	56	418	775
	UH-1H	204-040-600-7	63	625	889	48	640	1174
		204-040-600-9	73	506	506	60	515	862

UH-1/AH-1 M&R monitoring program revealed that the use rate, gross weights, and general treatment of the aircraft were much more severe in the combat environment. This factor was particularly significant for the higher powered UH-1H and AH-1G.

Although the operator's manuals restricted the engine power to 1100 shp, the engine had output torque values equivalent to 1400 hp at 6600 rpm for military rating and 1250 hp at 6600 rpm for normal rating. The 1100 shp was frequently exceeded when the aircraft were operated under the stress of combat conditions.

Table XXVI presents the significant failure modes for material failure- and external-failure-caused removals observed for each type of component when the data in Appendix II for each of the part numbers and for each of the aircraft models are combined. For all components, three failure modes make up 80 percent of the material-failure-caused removals. Excessive wear is a significant failure mode for all components. Except for the tail rotor hub and blade, sudden stoppage is the most significant external-failure-caused failure mode.

6.2.2.2 Estimating MTBR From Component MTBF

Table XXVII shows the results of estimating the MTBR of the components using equation (27), which considers removals for failures and time change only. The resulting $MTBR_e$ is a significant increase over the "All Causes" of removal MTBR observed in the basic analysis. The basic reason for this difference is the large percentage of components that are removed for reasons other than failures and time change that are later reinstalled on either the same or other aircraft and are ultimately removed for failure or time change at a higher total time.

TABLE XXVI. SIGNIFICANT FAILURE MODES OBSERVED IN THE RAMMIT MIRF REPORTS DATA ANALYSES

Component	Material Failures (MF) (% of All Failures)		External Failure Causes (EFC) (% of All Failures)	
	Failure Mode	% of MF	Failure Mode	% of ECF
Tail Rotor Hub	MF(64%)		EFC (36%)	
	Excessive Wear	59%	Accident/Crash	23%
	Bearing Failure	11%	Sudden Stoppage	23%
	Clogged	11%	Overspeed	16%
Tail Rotor Blade	MF(13%)		EFC(87%)	
	Excessive Wear	46%	Chipped, Nicked, etc.	21%
	Unbalanced	24%	Battle Damage/Punctured	20%
	Poor Bond	16%	Dented	16%
			Accident/Crash Damage	13%
42° Gearbox	MF(69%)		EFC(31%)	
	Leaking	67%	Sudden Stop	43%
	Excessive Wear	14%	Accident/Crash Damage	29%
	Contamination	6%	Overstressed	6%
	Internal Failure	6%		
90° Gearbox	MF(69%)		EFC(31%)	
	Leaking	55%	Sudden Stop	40%
	Excessive Wear	13%	Accident/Crash Damage	26%
	Contamination	12%	Overstressed	9%
Hanger Assembly	MF(82%)		EFC(18%)	
	Excessive Wear	56%	Sudden Stoppage	37%
	Bearing Failure	21%	Accident/Crash Damage	32%
	Leakage	17%		

TABLE XXVII. SUMMARY OF MTBF/MTBR VALUES OBTAINED FROM ANALYSIS OF RAMMIT MIRF DATA

Component (Time Change) Part Number	Model	MTBF		Mean-Time-Between-Removals	
		All Failures	Material Failures Only	All Causes	For Failures* and Time Change Only
Tail Rotor Hubs (1100-Hour Life)					
204-011-701-11	UH-1D	1012	1519	389	671
204-011-701-19	UH-1D	1558	2854	151	789
204-011-801-5	UH-1D	1040	1320	318	679
204-011-801-9	UH-1D	612	802	238	511
204-011-701-19	UH-1H	1850	3603	157	829
204-011-801-5	UH-1H	852	1264	264	618
204-011-801-9	UH-1H	746	1050	308	575
All D/H Hubs	D/H	1004	1511	215	668
209-011-701-3	AH-1G	632	2002	126	521
204-011-801-3	AH-1G	535	740	235	467
All G Hubs	AH-1G	569	979	176	437
All Hubs	D/H/G	899	1393	208	634
T/R Blades (1100 Hour Life)					
204-011-702-15	UH-1D	1335	8465	354	749
204-011-702-15	UH-1H	871	7765	319	625
All D/H Blades	D/H	924	7981	322	643
204-011-702-17	AH-1G	638	4292	221	524
All Blades	D/H/G	857	6947	298	620

TABLE XXVII. (Cont'd)

Component (Time Change) Part Number	Model	MTBF All Failures	MTBF Material Failures Only	Mean-Time-Between-Removals All Causes	Mean-Time-Between-Removals For Failures * and Time Change Only
42° Gearbox (1500 Hour TBO)					
204-040-003-23	UH-1D	1637	2692	717	982
204-040-003-37	UH-1D	1575	2333	757	967
204-040-003-37	UH-1H	1076	1545	656	809
All D/H 42's	D/H	1271	1863	696	881
204-040-003-37	AH-1G	924	1317	572	742
All 42's	D/H/G	1206	1817	675	858
90° Gearbox (1100 Hour TBO)					
204-040-012-7	UH-1D	1791	2961	729	822
204-040-012-13	UH-1D	1624	2405	697	799
204-040-012-13	UH-1H	1146	1615	614	707
All D/H 90's	D/H	1311	1886	647	744
204-040-012-13	AH-1G	982	1478	550	662
All 90's	D/H/G	1253	1817	632	732
D/S Hanger Assembly (None)					
204-040-600-7	UH-1D	645	814	373	645
204-040-600-9	UH-1D	665	775	430	665
204-040-600-7	UH-1H	889	1174	560	886
204-040-600-9	UH-1H	709	862	515	708
All D/H Hangers	D/H	693	846	465	692
204-040-600-9	AH-1G	652	794	435	652
All Hangers	D/H/G	689	840	462	689

* An MTBR which considers only failures and time change removal causes. It is estimated using equation (27) and the "All Failures" MTBF.

7. REPAIR-VERSUS-SCRAP ANALYSIS

The analysis of repairable and scrap (nonrepairable) components of the tail rotor drive system has been limited to the tail rotor hub and blade assemblies, tail rotor drive shaft and hanger assemblies, 42-degree and 90-degree gearboxes, and tail rotor control quill assemblies. The remaining tail rotor system components when failing are considered nonrepairable and are scrapped during corrective maintenance.

The repairable and scrap components fall into three categories--limited (finite) life components, components with specified times between overhaul (TBO), and selected condition components. The technical bulletin on aircraft component replacement and re-use procedures establishes basic criteria for repair and scrap for these components.[21] Limited life components are retired from service (scrapped) after reaching an established maximum allowable operating time (MAOT) since new. If a failure occurs before the component retirement life is reached, the component will be repaired if it is repairable and has more than 100 hours of the established MAOT remaining, or scrapped if it has less than 100 hours remaining. The tail rotor hub and blade are limited life items and are assigned a MAOT of 1100 hours.

TBO components are subject to restoration, through overhaul, when removed from service after reaching a MAOT since new or overhaul. If a failure occurs before the TBO schedule is reached, the component will be repaired if it has more than 200 hours of the established MAOT remaining and overhauled if it has less than 200 hours remaining. The 42-degree and 90-degree gearboxes are TBO items.

Selected condition components are overhauled/repaired when necessary ("on condition") rather than at a particular TBO interval. "On condition" overhaul items are tail rotor hanger assemblies. "On condition" repair items are the tail rotor driveshafts and control quill assemblies.

This analysis will present a percentage comparison of components repaired to components scrapped.

7.1 REPAIR-VERSUS-SCRAP ANALYSIS APPROACH

The data analyzed were card records of overhaul, repair, and scrap tail rotor system components reported on the UH-1C/D/H and AH-1G helicopters. The data sources were Army TAMMS DA 2407 unsheduled maintenance data and BHC overhaul data.

7.1.1 TAMMS 2407 Unscheduled Maintenance Data

The TAMMS DA 2407 data were analyzed to determine what percentage of all maintenance actions results in the scrapping of a component. The five coded actions in these data which indicate that maintenance was performed on an item are:

- Checked, not repairable
- Removed and reinstalled
- Repaired
- Not repairable this station
- Replaced

It was assumed that the first action indicates that the item was scrapped, the next three actions indicate that the item was repaired. The last action is an unknown--it does not indicate the disposition of the removed component.

The TAMMS maintenance data were analyzed by first identifying the component, the component part number, and the disposition of the component, i.e., repaired, scrapped, or forwarded to a repair facility, and second expressing as percentages of the total component maintenance actions, the number of the components repaired and scrapped.

7.1.2 BHC Overhaul Data

The analysis of the data on components overhauled at BHC was performed by identifying the:

- Component overhauled
- Component part number
- Total number of components processed, i.e., overhauled, repaired, or scrapped
- Total number of components processed for which accumulated operating time is reported
- MTR of the components processed for which accumulated operating time is reported
- Total number of components scrapped

- Total number of components scrapped for which accumulated operating time was reported

- Percentage of the total number of components processed that were scrapped.

7.2 REPAIR-VERSUS-SCRAP ANALYSIS RESULTS

7.2.1 TAMMS Data Analysis

Tables XXVIII through XXXI present the percentage repaired, scrapped, and with unknown disposition for the components being analyzed. The tail rotor control items, other than the quill assemblies, were considered scrapped whenever replaced. The percentage of tail rotor drive system components and the tail rotor hub and blade assembly components that were scrapped cannot be determined because three-fourths or more of the maintenance actions considered were coded "replaced," which is a "disposition unknown" action. It was assumed that whenever a sprocket was replaced, a tail rotor control quill assembly was being repaired. This placed the majority (from 53-97 percent) of the control quills in the "repaired" category. None of the control quills were identified as scrapped. It is concluded that it is not possible to determine the complete percentage of repair or scrappage of any tail rotor system repairable item from the TAMMS data.

7.2.2 BHC Overhaul Data Analysis

Table XXXII presents a scrap analysis of tail rotor components processed at BHC which are overhaul or limited-life items. The limited-life items have much higher scrap rates than overhaul items.

TABLE XXVIII. REPAIR-VERSUS-SCRAP ANALYSIS OF UH-1C TAIL ROTOR COMPONENTS

(Based on Unscheduled Maintenance Actions from TAMMS 2407 Data)

SUBSYSTEM Components	Bell Part Number	Disposition as a % of Total		
		Repair	Scrap	Unknown
T/R HUB & BLADE	204-011-701-017	10.0	-	90.0
Hub Assembly	204-011-701-013	8.3	-	91.7
	204-011-701-019	5.7	-	94.3
	204-011-801-005	*	*	*
	204-011-801-009	*	*	*
T/R Blade	204-011-702-017	7.5	0.1	92.4
T/R DRIVE				
T/R Drive Shaft	204-040-620-003	3.1	-	96.9
Hanger Assembly	204-040-600-007	1.7	-	98.3
	204-040-600-009	3.1	-	96.9
42° Gearbox	204-040-003-023	*	*	*
	204-040-003-037	4.0	1.0	95.0
90° Gearbox	204-040-012-007	*	*	*
	204-040-012-013	1.6	-	98.4
T/R CONTROL				
Quill Assembly	204-010-740-005	68.8	-	31.2

* Data are inadequate

TABLE XXIX. REPAIR-VERSUS-SCRAP ANALYSIS OF UH-1D TAIL ROTOR COMPONENTS

(Based on Unscheduled Maintenance Actions from TAMMS 2407 Data)

SUBSYSTEM Components	Bell Part Number	Disposition as a % of Total Repair	Scrap	Unknown
T R HUB & BLADE	204-011-701-009	11.3	-	88.7
	204-011-701-015	25.8	-	74.2
Hub Assembly	204-011-701-011	*		*
	204-011-701-013	0.[illegible]		99.3
	204-011-701-019	2.[illegible]		97.9
	204-011-701-029	7.1	-	92.9
	204-011-801-005	*		*
	204-011-801-009	-	-	100.0
T/R Blade	204-011-702-015	1.8	0.1	98.1
T/R DRIVE				
T/R Drive Shaft	204-040-620-003	2.5	1.4	96.1
	204-040-620-005	3.7	3.1	93.2
Hanger Assembly	204-040-600-007	1.0	0.3	98.7
	204-040-600-009	0.9	-	99.1
42° Gearbox	204-040-003-023	3.8	1.4	95.8
	204-040-003-037	3.5	-	96.5
90° Gearbox	204-040-012-007	5.3	-	94.7
	204-040-012-013	1.9	-	98.1
T/R CONTROL				
Quill Assembly	204-010-740-003 204-010-740-005	53.3	-	46.7

* Data are inadequate

TABLE XXX. REPAIR-VERSUS-SCRAP ANALYSIS OF UH-1H TAIL ROTOR COMPONENTS

(Based on Unscheduled Maintenance Actions from TAMMS 2407 Data)

SUBSYSTEM Components	Bell Part Number	Disposition as a % of Total		
		Repair	Scrap	Unknown
T/R HUB & BLADE	204-011-701-015	18.0	-	82.0
Hub Assembly	204-011-701-013	-	-	100.0
	204-011-701-019	1.7	0.2	98.1
	204-011-801-009	15.2	-	84.8
T/R Blade	204-011-702-015	2.7	-	97.2
T/R DRIVE				
T/R Drive Shaft	204-040-620-003	1.7	-	98.3
	204-040-620-005	0.8	-	99.2
Hanger Assembly	204-040-600-009	4.2	-	95.8
42° Gearbox	204-040-003-037	5.2	-	94.8
90° Gearbox	204-040-012-013	5.0	0.2	94.8
T/R CONTROL				
Quill Assembly	204-010-740-003 204-010-740-005	88.2	-	11.8

TABLE XXIX. REPAIR-VERSUS-SCRAP ANALYSIS OF UH-1D TAIL ROTOR COMPONENTS

(Based on Unscheduled Maintenance Actions from TAMMS 2407 Data)

SUBSYSTEM Components	Bell Part Number	Disposition as a % of Total		
		Repair	Scrap	Unknown
T/R HUB & BLADE	204-011-701-009	11.3	-	88.7
	204-011-701-015	25.8	-	74.2
Hub Assembly	204-011-701-011	*	*	*
	204-011-701-013	0.7	-	99.3
	204-011-701-019	2.1	-	97.9
	204-011-701-029	7.1	-	92.9
	204-011-801-005	*	*	*
	204-011-801-009	-	-	100.0
T/R Blade	204-011-702-015	1.8	0.1	98.1
T/R DRIVE				
T/R Drive Shaft	204-040-620-003	2.5	1.4	96.1
	204-040-620-005	3.7	3.1	93.2
Hanger Assembly	204-040-600-007	1.0	0.3	98.7
	204-040-600-009	0.9	-	99.1
42° Gearbox	204-040-003-023	3.8	1.4	95.8
	204-040-003-037	3.5	-	96.5
90° Gearbox	204-040-012-007	5.3	-	94.7
	204-040-012-013	1.9	-	98.1
T/R CONTROL				
Quill Assembly	204-010-740-003 204-010-740-005	53.3	-	46.7

* Data are inadequate

TABLE XXX. REPAIR-VERSUS-SCRAP ANALYSIS OF UH-1H TAIL ROTOR COMPONENTS

(Based on Unscheduled Maintenance Actions from TAMMS 2407 Data)

SUBSYSTEM Components	Bell Part Number	Disposition as a % of Total		
		Repair	Scrap	Unknown
T/R HUB & BLADE	204-011-701-015	18.0	-	82.0
Hub Assembly	204-011-701-013	-	-	100.0
	204-011-701-019	1.7	0.2	98.1
	204-011-801-009	15.2	-	84.8
T/R Blade	204-011-702-015	2.7	-	97.2
T/R DRIVE				
T/R Drive Shaft	204-040-620-003	1.7	-	98.3
	204-040-620-005	0.8	-	99.2
Hanger Assembly	204-040-600-009	4.2	-	95.8
42° Gearbox	204-040-003-037	5.2	-	94.8
90° Gearbox	204-040-012-013	5.0	0.2	94.8
T/R CONTROL				
Quill Assembly	204-010-740-003 204-010-740-005	88.2	-	11.8

TABLE XXXI. REPAIR-VERSUS-SCRAP ANALYSIS OF AH-1G TAIL ROTOR COMPONENTS

(Based on Unscheduled Maintenance Actions from TAMMS 2407 Data)

SUBSYSTEM Components	Bell Part Number	Disposition as a % of Total		
		Repair	Scrap	Unknown
T/R HUB & BLADE	209-010-701-001	25.0	-	75.0
Hub Assembly	204-011-801-003	3.0	-	97.0
	204-011-801-011	*	*	*
	209-010-701-003	4.0	-	96.0
T/R Blade	204-011-702-017	2.0	-	98.0
T/R DRIVE				
T/R Drive Shaft	204-040-620-003	2.0	-	98.0
	209-040-611-001	-	-	100.0
Hanger Assembly	204-040-600-009	4.4	-	95.6
42° Gearbox	204-040-003-037	6.9	-	93.1
90° Gearbox	204-040-012-013	2.0	-	98.0
T/R CONTROL				
Quill Assembly	204-010-740-005	97.0	-	3.0

* Data are inadequate

TABLE XXXII. TAIL ROTOR COMPONENT DEPOT-LEVEL SCRAP ANALYSIS

(Based on BHC Overhaul Data thru 1970)

Component Part Number	No. of Items Processed		MTR (hrs)	No. of Items Scrapped		MTR (hrs)	Percent Scrapped Using Total Number
	Total	With* Time		Total	With* Time		
Hanger Assembly							
204-040-600-7	2966	2666	678	3	3	1054	0.10
-9	616	614	381	1	1	500	0.16
42° Gearbox							
204-040-003-23	757	679	941	15	13	536	1.98
-37	2928	2903	915	16	16	786	0.55
90° Gearbox							
204-040-012-7	580	499	817	33	29	418	5.69
-13	4020	4002	770	54	53	559	1.34
T/R Hub							
204-011-701-11	21	19	610	5	3	1157	23.81
209-010-701-3	3	2	61	0	0	-	0.00
T/R Blade							
204-011-702-15	576	535	412	398	360	459	69.10
-17	5	5	63	3	3	79	60.00

* The number of items processed for which a removal time is known.

8. MAINTENANCE PERSONNEL REQUIREMENTS ANALYSIS

8.1 Maintenance Personnel Requirements Analysis Approach

The maintenance personnel requirements for this analysis were obtained from the UH-1C/D/H and AH-1G helicopter maintenance manuals,[1,2,3] and the Enlisted Military Occupational Specialties (MOS manual).[22]

The maintenance personnel requirement analysis was performed by establishing the:

- Maintenance personnel types
- Maintenance tasks
- Maintenance organizations
- Quantity of men required per task
- Average number of men required per maintenance action

8.1.1 Maintenance Personnel Types

In identifying the personnel requirements, the MOS selected from the data sources is the lowest skill level of maintenance personnel authorized to perform the maintenance function. The four types of personnel authorized to perform maintenance on tail rotor system components are:

- UH-1C/D/H helicopter repairman (MOS 67N20)
- AH-1G helicopter repairman (MOS 67Y20)
- Aircraft powertrain repairman (MOS 68D20)
- Aircraft rotor and propeller repairman (MOS 68E20)

8.1.2 Maintenance Tasks

The lowest skill level of personnel authorized to perform a maintenance function is dictated by the task's level of technical difficulty. The maintenance tasks, grouped by skill level, are shown below.

8.1.2.1 Lower Skill Level

The lower skill level tasks are assigned to MOS 67N20 and 67Y20 personnel. The lower skill level tasks ranked by increasing difficulty, are:

- Service: To clean, to preserve, to change, and to add fuel, lubricant, cooling agents and air.

- Replace: To replace unserviceable items with serviceable assemblies, subassemblies or parts.

- Adjust: rectify to the extent necessary to bring into prop. operating range.

- Align: To adjust specified variable elements of an item to bring to optimum performance.

8.1.2.2 Higher Skill Level

The higher skill level tasks are assigned to MOS 68D20 and 68E20 personnel. The higher skill level tasks ranked by increasing difficulty, are:

- Test: To verify serviceability and to detect electrical or mechanical failure by the use of test equipment.

- Inspect: To determine serviceability of an item by comparing its physical, mechanical, and electrical characteristics with established standards.

- Repair: To restore an item to serviceable condition through correction of a specific failure or unserviceable condition. This includes, but is not limited to, inspections, cleaning, preserving, adjusting, replacing, welding, riveting and strengthening.

- Overhaul: To restore an item to completely serviceable condition as prescribed by maintenance serviceability standards prepared and published for the specific item to be overhauled.

8.1.3 Maintenance Organizations

The Army's maintenance organization is divided into four main categories: Organizational (Org), Direct Support (D/S), General Support (G/S), and Depot (D). The description of each maintenance category is presented in the following paragraphs.

8.1.3.1 Organizational Maintenance

Organizational maintenance is that maintenance normally authorized for, performed by, and is the responsibility of a using organization on equipment in its possession. This maintenance is normally restricted to periodic checks of equipment performance, cleaning, servicing, preserving, and adjusting the equipment, and removal and replacement of some components.

8.1.3.2 Direct Support Maintenance

Direct support maintenance is that maintenance normally authorized and performed by designated maintenance activities in direct support of using organizations. This category of maintenance includes inspections, complicated adjustments, major repairs and modifications, major replacement of components, and overloads from organizational maintenance.

8.1.3.3 General Support

General support maintenance is that maintenance authorized and performed by designated organizations in support of the Army supply system. General support maintenance organizations will repair or overhaul components to required maintenance standards. The general support primary maintenance function is to repair those items that cannot be repaired at the direct support level.

8.1.3.4 Depot Maintenance

Depot maintenance is that maintenance which, through overhaul of economically repairable material, augments the procurement program in satisfying overall Army requirements and, when required, provides for repair of material beyond the capability of general support maintenance organizations.

8.1.4 Manpower Requirements

In the basic manpower requirements analysis, the number of men required to perform each tail rotor system maintenance task was extracted from maintenance engineering analyses on the Navy UH-1N and AH-1J helicopters, performed per Navy WR6 requirements.[23, 24]

To determine the manpower requirements based on field experience, the average number of men required to perform a

maintenance task was obtained from Navy 3-M data on the UH-1D and AH-1G using the equation:

$$\overline{MM} = \frac{\sum_{i=1}^{n} MMH_i}{\sum_{i=1}^{n} EMT_i} \tag{31}$$

where $\overline{MM}$ = average number of maintenance men required to perform a maintenance task

MMH_i = maintenance manhours to perform task i

EMT_i = elapsed maintenance time to perform task i

n = the number of tasks performed

8.2 MAINTENANCE PERSONNEL REQUIREMENTS ANALYSIS RESULTS

Tables XXXIII through XXXV present the personnel requirements for organizational maintenance actions of the tail rotor components. Tables XXXIII and XXXIV are the maintenance manpower requirements for the UH-1C/D/H and AH-1G, respectively, determined by maintenance engineering analysis.

The quantity of men required per maintenance task is designated as one or two. Two indicates that two men are required for at least a portion of the total task time, but both men are not necessarily required for the entire period.

Table XXXV is a summary of the average number of men required per maintenance action as determined from the Navy 3-M data analysis. It shows that with two exceptions the average for all tasks ranges from one to less than two men. The fraction over one is the fraction of the task time that the second man is required, on the average.

Table XXXVI presents the military occupation specialties (MOS) personnel authorized to perform maintenance on the tail rotor system and the maintenance organizations to which they are allocated.

TABLE XXXIII. UH-1C/D/H MAINTENANCE MANPOWER REQUIREMENTS

MOS Maintenance Task	Maint. Level	Model UH-1	Men Reqd.	Components
67N20				
Inspect	Org	C/D/H	1	All Components
Test*	Org	C/D/H	1	42° Gearbox
	Org	C/D/H	1	90° Gearbox
	Org	C/D/H	1	T/R Pitch Control Mechanism
Service	Org	D/H	1	All components serviced except T/R Blades
	Org	C	1	T/R Blades - Tracking
Adjust	Org	D/H	1	T/R Hub & Bld. Assembly
	Org	C/D/H	1	T/R Blades - Tracking
	Org	D/H	1	T/R Pitch Control Mechanism - Rigging
Align	D/S	C/D/H	2	T/R Drive Shaft
Replace	Org	D/H	2	T/R Hub & Bld. Assembly
	Org	C	1	T/R Blades
	Org	C/D/H	1	T/R Drive Shaft
	Org	C/D/H	1	Hanger Assemblies
	Org	C/D/H	1	42° Gearbox
	Org	C/D/H	1	90° Gearbox
	D/S	C/D/H	2	T/R Hub
	D/S	D/H	1	T/R Blades
Repair	Org	C	1	T/R Drive Shaft
	Org	D/H	1	T/R Drive Shaft -Requires use of special tool
68D20				
Replace	Org	D/H	1	T/R Pitch Control Mechanism
Repair	D/S	C	1	Hanger Assemblies
	D/S	C/D/H	1	42° and 90° Gearboxes
	D/S	D/H	1	T/R Pitch Control Mechanism
	G/S	D/H	1	Hanger Assemblies

TABLE XXXIII. (Cont'd)				
MOS Maintenance Task	Maint. Level	Model UH-1	Men Reqd.	Components
Overhaul	D/S	C/D/H	1	42° and 90° Gearboxes
68E20				
Adjust	D/S	C	1	T/R Hub & Blade Assembly Balancing
Align	D/S	D/H	1	T/R Hub & Blade Assembly
Repair	Org** D/S	C/D/H C/D/H	1 1	T/R Blades T/R Hub

* Maintenance operational check (Ref. TB-AVN-23-16)

** An organizational maintenance function which may be performed provided it is specifically authorized by the direct support maintenance officer.

TABLE XXXIV. AH-1G MAINTENANCE MANPOWER REQUIREMENTS

MOS Maintenance Task	Maint. Level	Men Reqd.	Components
67Y20			
Inspect	Org	1	All Components
Serivce	Org	1	All Components Serviced
Adjust	Org	1	Hub and Blade Assembly
	Org	1	T/R Llades - Tracking
Align	D/S	2	T/R Drive Shaft
	D/S	2	Hanger Assemblies
Replace	Org	2	Hub and Blade Assembly
	Org	2	42° Gearbox
	Org	2	90° Gearbox
	Org	1	T/R Drive Shaft
	Org	1	Hanger Assemblies
	D/S	2	T/R Hub
	D/S	1	T/R Blade
Repair	Org*	1	T/R Drive Shaft
68D20			
Replace	Org	1	T/R Pitch Control Mechanism
	D/S	1	Quills (42° and 90° Gearboxes)
Repair	D/S	1	42° Gearbox
	D/S	1	90° Gearbox
	D/S	1	Quill (42° and 90° Gearboxes)
	D/S	1	T/R Pitch Control Mechanism
Overhaul	G/S	1	Hanger Assemblies
	D	1	T/R 42° and 90° Gearboxes
	D	1	Quills (42° and 90° Gearboxes)

TABLE XXXIV. (Cont'd)			
MOS Maintenance Task	Maint. Level	Men Reqd.	Components
68E20			
Align	D/S	1	T/R Hub and Blade Assembly
Repair	Org**	1	T/R Blades
	D/S	1	T/R Hub

* Painting of the tail rotor drive shaft must be done at the Depot Maintenance level because painting can cause an unbalanced condition which would require rebalancing.

** An organizational maintenance function which may be performed provided it is specifically authorized by the direct support maintenance officer.

TABLE XXXV. AVERAGE NUMBER OF MEN REQUIRED PER MAINTENANCE ACTION

(3-M Data through February 1972)

SUBSYSTEM	All Maint		Part Repl		On A/C Repair	
Component	AH-1G	UH-1D	AH-1D	UH-1D	AH-1G	UH-1D
T/R HUB & BLADE						
T/R Hub	1.19	1.61	1.16	1.57	1.26	1.64
T/R Blade	1.08	1.57	2.62	1.62	1.04	1.51
Other	1.17	1.64	1.15	1.33	1.17	1.67
T/R DRIVE						
T/R Drive Shaft	1.17	1.53	1.23	1.70	1.09	1.40
Hanger Assy	1.17	1.46	1.13	1.30	1.48	1.72
42° Gearbox	1.27	1.59	1.36	1.71	1.06	1.52
90° Gearbox	1.46	1.65	1.53	1.72	1.27	1.63
T/R D/S Clamp	1.00	1.54	1.00	1.67	1.00	1.50
Other	1.18	1.26	1.02	1.75	1.24	1.23
T/R CONTROL						
Control Quill*	1.00	1.45	1.00	1.50	1.00	1.38
Control Tube	1.10	1.86	1.00	1.86	1.67	-
Pitch Control Mechanism**	1.02	1.39	1.06	1.73	1.00	1.27
Chain	1.03	1.96	1.05	2.06	1.00	1.76
Pitch Change Link	1.14	1.47	1.22	1.60	1.10	1.38
Crosshead	1.12	1.32	1.00	1.05	1.17	1.37

*Includes sprocket wheel
**Includes cone set, static stop, nut, boot, slider, plate, crosshead bearing.

TABLE XXXVI. MOS PERSONNEL AND MAINTENANCE ALLOCATIONS

MOS	Maintenance Level			
	Organizational	Direct Support	General Support	Depot
67N20	X	X	X	X
67Y20	X	X	X	X
68D20		X	X	X
68E20		X	X	X

9. MAINTENANCE MAN-HOURS PER FLIGHT HOUR (MMH/FH) ANALYSIS

9.1 MMH/FH ANALYSIS APPROACH

MMH/FH is the average number of maintenance man-hours expended per aircraft flight hour to perform the scheduled and unscheduled maintenance required to support a specified item. For this analysis the specified item is the tail rotor system. The basic equation for the computation is:

$$\text{MMH/FH} = \frac{\sum_{i=1}^{n} t_{m_i}}{\sum_{j=1}^{m} t_j} \qquad (32)$$

where t_{m_i} = the maintenance man-hours expended to perform task i on the equipment

n = the total number i maintenance tasks performed on the equipment

t_j = the total time accrued on aircraft j during the period that the equipment was installed on the aircraft

m = the total number of aircraft on which the equipment was installed

The only source found that provides the necessary elements for the computation is the Navy 3-M data. It contains both flight time and maintenance time. However, it identifies the tail rotor system components only by work unit code and it does not provide depot maintenance reports to analyze. The MMH/FH analysis has been performed for organizational and intermediate maintenance for the UH-1D and AH-1G tail rotor systems. The Navy's intermediate maintenance is similar to the Army's direct and general support maintenance.

In the organizational maintenance analysis of the Navy 3-M data, the maintenance actions were divided into two groups: actions which involved part replacements and actions which involved on-aircraft repairs. Each of these groups was further divided into scheduled and unscheduled maintenance actions.

The scheduled actions are "time change" and scheduled maintenance" actions, determined by the malfunction code. The rest of the malfunction codes are classed as unscheduled maintenance actions.

The intermediate maintenance records within the 3-M data analyses could not be subdivided in the same manner as the organizational maintenance data. However, they can be summed by component subsystem and for each total tail rotor system.

9.2 MMH/FH ANALYSIS RESULTS

The MMH/FH expended in organizational and intermediate maintenance are shown in Table XXXVII for each subsystem and for the tail rotor system for model UH-1D and AH-1G aircraft. The significant difference between the two models is the much greater expenditure of intermediate maintenance for the tail rotor subsystem of the UH-1D. Table XXXVIII shows how the intermediate maintenance is subdivided among the components within the subsystems. Here it can be seen that most of the intermediate-level support was for the tail rotor hub and hanger assemblies. During this period the 701-hubs underwent frequent inspections. The hanger assembly can be overhauled by the intermediate maintenance level, while the 42- and 90-degree gearboxes must be overhauled at depot level. It is not possible to determine the percentage of hanger assemblies removed which were forwarded to depot maintenance for overhaul.

Table XXXIX shows the tail rotor subsystem grouping of organizational maintenance man-hours per flight hour subdivided by part replacement and on-aircraft repair for both scheduled and unscheduled maintenance. The results for the two models show that while there are significant differences between the comparable maintenance actions, the organizational MMH/FH for the UH-1D tail rotor system is more than 97 percent of the value for the AH-1G.

Table XL presents the maintenance man-hours per million flight hours expended for the tail rotor system components.

From a maintenance standpoint, the following components are critical in that they require the greater percentage of maintenance man-hours expended for the model's tail rotor system. Together, these components account for almost ninety percent of the organizational maintenance man-hours expended.

- AH-1G

90° Gearboxes	22%
Tail Rotor Hubs	21%
Hanger Assemblies	18%
42° Gearboxes	10%
Tail Rotor Blades	7%
Pitch Change Links	6%
Tail Rotor Drive Shafts	5%

- UH-1D

Tail Rotor Hubs	28%
90° Gearboxes	24%
42° Gearboxes	11%
Tail Rotor Blades	9%
Hanger Assemblies	7%
Pitch Change Links	5%
Tail Rotor Drive Shafts	5%

TABLE XXXVII. TAIL ROTOR SYSTEM MAINTENANCE MAN-HOURS PER FLIGHT HOUR

(3-M Data Through February 1972)

MODEL Subsystem	Maintenance Level		Both Levels
	Organizational	Intermediate	
UH-1D			
T/R Hub & Blade	0.028347	0.040859	0.069206
T/R Drive	0.031375	0.004574	0.035949
T/R Control	0.007954	0.000024	0.007978
Total T/R System	0.067676	0.045457	0.113133
AH-1G			
T/R Hub & Blade	0.025736	0.005537	0.031273
T/R Drive	0.035421	0.005063	0.040484
T/R Control	0.009798	0.0	0.009798
Total T/R System	0.070955	0.010600	0.081555

TABLE XXXVIII. TAIL ROTOR SYSTEM INTERMEDIATE MAINTENANCE MAN-HOURS PER FLIGHT HOUR (3-M Data Through February 1972)

SUBSYSTEM Component	UH-1D Org. + Int. Maint. MMH/FH	UH-1D Int. Maint. MMH/FH	UH-1D Int. % of Org. + Int. Maint.	AH-1G Org. + Int. Maint. MMH/FH	AH-1G Int. Maint. MMH/FH	AH-1G Int. % of Org. + Int. Maint.
T/R HUB & BLADE	0.069206	0.040859	59.0	0.031273	0.005537	17.7
T/R Hub	0.055916	0.038977	69.7	0.018226	0.005477	30.1
T/R Blade	0.006366	0.001288	20.2	0.004602	0.000033	0.7
Other	0.006924	0.000594	8.6	0.008445	0.000027	0.3
T/R DRIVE	0.035949	0.004574	12.7	0.040484	0.005063	12.5
T/R Drive Shaft	0.003140	0.000074	2.4	0.003223	0.000099	3.1
Hanger Assembly	0.007693	0.003449	44.8	0.016170	0.004957	30.7
42° Gearbox	0.006637	0.000210	3.2	0.005955	0.000007	0.0
90° Gearbox	0.014939	0.000742	5.0	0.013349	0.0	0.0
T/R D/S Clamp	0.000947	0.0	0.0	0.000242	0.0	0.0
Other	0.002591	0.000099	3.8	0.001545	0.0	0.0
T/R CONTROLS	0.007978	0.000024	0.3	0.009798	0.0	0.0
Chain	0.001236	0.0	0.0	0.000809	0.0	0.0
Quill Assembly	0.000477	0.0	0.0	0.000620	0.0	0.0
Control Tube	0.000173	0.000012	6.9	0.000763	0.0	0.0
Crosshead	0.002109	0.0	0.0	0.002659	0.0	0.0
Pitch Change Link	0.003278	0.000012	0.4	0.003737	0.0	0.0
Pitch Change Mechanism	0.000705	0.0	0.0	0.001210	0.0	0.0

TABLE XXXIX. TAIL ROTOR SYSTEM ORGANIZATIONAL LEVEL MAINTENANCE MAN-HOURS PER FLIGHT HOUR

MODEL Maintenance	Tail Rotor Subsystems: T/R Hub & Blade	Tail Rotor Subsystems: Drive System	Tail Rotor Subsystems: Controls	Total Tail Rotor System
UH-1D				
On A/C Repair	0.0150	0.0203	0.0048	0.0401
Scheduled	0.0026	-	-	0.0026
Unscheduled	0.0124	0.0203	0.0048	0.0375
Part Replacement	0.0133	0.0111	0.0032	0.0276
Scheduled	0.0011	0.0018	-	0.0029
Unscheduled	0.0122	0.0093	0.0032	0.0247
All Maintenance	0.0283	0.0314	0.0080	0.0677
Scheduled	0.0037	0.0018	-	0.0055
Unscheduled	0.0246	0.0296	0.0080	0.0622
AH-1G				
On A/C Repair	0.0107	0.0087	0.0054	0.0248
Scheduled	0.0006	0.0002	-	0.0008
Unscheduled	0.0101	0.0085	0.0054	0.0240
Part Replacement	0.0150	0.0267	0.0044	0.0461
Scheduled	0.0050	0.0003	-	0.0053
Unscheduled	0.0100	0.0264	0.0044	0.0408
All Maintenance	0.0257	0.0354	0.0098	0.0709
Scheduled	0.0056	0.0005	-	0.0061
Unscheduled	0.0201	0.0349	0.0098	0.0648

TABLE XL. TAIL ROTOR SYSTEM COMPONENTS MAINTENANCE MAN-HOURS PER MILLION FLIGHT HOURS

(From 3-M Data Through February 1972)

SUBSYSTEM	All Maintenance						Part Replacement						On A/C Repair					
	AH-1G			UH-1D			AH-1G			UH-1D			AH-1G			UH-1D		
Component	Total	Sched.	Unsched.	Total	Sched.	Unsched.	Total	Sched.	Unsched.	Total	Sched.	Unsched.	Total	Sched.	Unsched.	Total	Sched.	Unsched.
T/R HUB & BLADE ASSY.																		
T/R Hub	12749	5199	7550	16939	3224	13715	9277	4559	4718	10311	593	9718	3472	640	2832	6628	2631	3997
T/R Blade	4569	408	4161	5078	371	4707	3518	408	3110	2549	371	2178	1051	-	1051	2529	-	2529
Other	8418	-	8418	6331	57	6244	2225	-	2225	494	57	407	6193	-	6193	5837	-	5837
T/R DRIVE SYSTEM																		
T/R Drive Shaft	3123	-	3123	3065	-	3065	2132	-	2132	1463	-	1463	991	-	991	1602	-	1602
Hanger Assy's	11214	33	11181	4245	-	4245	9350	-	9350	2163	-	2163	1564	33	1531	2082	-	2082
42° Gearbox	5948	133	5815	6427	311	6116	4370	-	4370	2608	311	2297	1578	133	1445	3819	-	3819
90° Gearbox	13349	298	13051	14197	1533	12664	10461	298	10163	4566	1533	3033	2588	-	2588	9631	-	9631
T/R D/S Clamps	242	-	242	949	-	949	10	-	10	124	-	124	232	-	232	825	-	825
Other	1545	-	1545	2492	-	2492	345	-	345	173	-	173	1200	-	1200	2319	-	2319
T/R CONTROLS																		
Control Quill*	620	-	620	477	-	477	464	-	464	297	-	297	156	-	156	180	-	180
Control Tube	763	-	763	161	-	161	597	-	597	161	-	161	166	-	166	-	-	-
Pitch Control Mechanism**	1210	-	1210	705	-	705	580	-	580	235	-	235	630	-	630	470	-	470
Chain	809	-	809	1236	-	1236	607	-	607	865	-	865	202	-	202	371	-	371
Pitch Change Links	3737	-	3737	3266	-	3266	1509	-	1509	1407	-	1407	2228	-	2228	1859	-	1859
Crosshead	2659	-	2659	2109	-	2109	693	-	693	247	-	247	1966	-	1966	1862	-	1862

* Includes sprocket wheel
** Includes cone set, static stop, nut, boot slider, plate, crosshead bearing

10. FAILURE MODE ANALYSIS

10.1 FAILURE MODE ANALYSIS APPROACH

The failure modes and failure rates for this analysis were obtained from the UH-1/AH-1 M&R Program Failure/Discrepancy Report (FDR) data on Army UH-1C/D/H and AH-1G helicopters and a time base of 178,000 monitored flight hours.

The failure mode analysis was performed by identifying:

- The mode of failure
- The cause of failure
- The classification of failure by increasing severity per reference Paragraph 3.14 of MIL-STD-882:[25]
  Negligible (Category I)
  Marginal (Category II)
  Critical (Category III)
  Catastrophic (Category IV)
- The component primary and secondary (dependent) individual failure mode failure rates
- The average and total component failure rates for both primary and secondary failures
- The combat damage as a primary failure mode

Primary failure rates were determined for modes caused by inherent failures, induced failures, and combat damage. Secondary failure rates were determined for modes caused by primary failures. The component failure mode rates and the total component failure rates were determined using the following ations:

$$\lambda_M = \frac{f_M}{k \sum_{j=1}^{m} t_j} \times 1{,}000{,}000 \qquad (33)$$

where λ_M nent failure mode rate in failures per million t hours

f_M = of item failures of a specific failure mode uring the monitoring period

t_j = total flight hours of the jth aircraft during the monitoring period

m = the number of aircraft in the group

k = the number of like components per aircraft

$$\lambda_{TC} = \sum_{i=1}^{r} \lambda_{M_i} \tag{34}$$

where λ_{TC} = total component failure rate in failures per million flight hours

λ_{M_i} = total component failure mode rates of the ith failure mode

r = the number of failure modes identified for the component

The total subsystem failure rate and the average component failure rate were computed using the following equations:

$$\lambda_{SS} = \sum_{h=1}^{s} k_h \lambda_{TC_h} + \lambda_O \tag{35}$$

where λ_{SS} = total subsystem failure rate in failures per million flight hours

λ_{TC_h} = total component failure rate of the hth component

λ_O = "other" component failure rate, i.e., failures reported against the subsystem as a whole and against miscellaneous connecting items of the subsystem

k_h = the number of like components within the subsystem

s = the number of different components in the subsystem

$$\overline{\lambda}_{C/S} = \frac{\sum_{h=1}^{s} k_h \lambda_{TC_h}}{\sum_{h=1}^{s} k_h} \tag{36}$$

where $\overline{\lambda}_{C/S}$ = average component failure rate for the components in the subsystem

10.2 FAILURE MODE ANALYSIS RESULTS

Table XLI presents the most frequent component failure modes observed on the tail rotor system. For most of the components

TABLE XLI. TAIL ROTOR SYSTEM MOST FREQUENT FAILURE MODES BY COMPONENT (M&R PROGRAM DATA)

Failure Mode	Cause	Class	Type	Aircraft Model
T/R HUB & BLADE				
T/R Blade				
T/R Blade Damaged By Armament Debris	Spent Brass Strike	III	Induced	D/H, C, G
T/R Blade Has Strike Damage	Contact Tree, Wire	III	Induced	D/H
T/R Hub				
T/R Hub Grip Bearings Worn/Loose/ Rough	Normal Wear/Sandy Environment	II	Inherent	D/H, C, G
T/R CONTROL				
T/R Control Quill Assembly				
T/R Control Quill Binding	Sand & Dirt in Bearing	II	Inherent	D/H, C, G
T/R Control Tube				
Splines Worn on T/R Control Tube	Overtorque, Maintenance Error	II	Induced	D/H, C
Threads Stripped on T/R Control Tube or Nut	Maintenance Error	III	Induced	D/H, G
T/R Crosshead				
T/R Crosshead Assembly Scored by P/C Link Bearing	Improper Alignment	III	Induced	D/H, G
T/R Chain				
T/R Chain Worn	Sand Contamination, Oil, Dust	II	Inherent	D/H, C, G

TABLE XLI. (Cont'd)

Failure Mode	Cause	Class	Type	Aircraft Model
<u>T/R Boot</u>				
T/R Boot Torn or Cut	Rough Handling, Maintenance Error	II	Induced	D/H, C, G
<u>T/R Slider</u>				
T/R Slider Worn	Normal Wear, Sandy Environment	II	Inherent	D/H, C, G
<u>Crosshead Bearing Set</u>				
Bearing Set Worn/Separating	Sandy Environment, Lack of Lube	II	Inherent	D/H, C, G
<u>T/R Pitch Change Link</u>				
T/R P/C Link Bearings Worn	Sandy Environment, Lack of Lube	II	Inherent	D/H, C, G
<u>T/R DRIVE</u>				
<u>Hanger Assembly</u>				
T/R D/S Hanger Bearing Failure	Sandy Environment, Lack of Lube	II	Inherent	D/H, C, G
<u>42^{o} Gearbox</u>				
42^{o} G/B Leaking at Input Quill	Seal Deteriorated, Sandy Environment	I	Inherent	D/H, C, G
<u>90^{o} Gearbox</u>				
90^{o} G/B Leaking at Input Quill	Seal Deterioration, Sandy Environment	I	Inherent	D/H, G
90^{o} G/B Has Metal Particles on Magnetic Plug	Unknown - Suspect Internal Wear	III	Inherent	G

TABLE XLI. (Cont'd)

Failure Mode	Cause	Class	Type	Aircraft Model
<u>90° Gearbox</u> (Cont'd)				
90° G/B Input Quill Has Inadequate Lube, D/S Bottoms Out	Lack of Lube	II	Inherent	C
90° G/B Damaged Internally	T/R Overload	III	Induced	G
<u>T/R Drive Shaft</u>				
T/R D/S Dented/Damaged	Blade Strike/Hard Landing/Unknown	II	Induced	D/H, C, G
T/R D/S Clamp Damaged	Unknown	II	Inherent	C

analyzed, one or two failure modes were predominant. These modes were responsible for most of the total component failure rate.

Table XLII summarizes the tail rotor system failure rates for the UH-1C/D/H and AH-1G aircraft. It presents the total primary and secondary failure rates for each component that has a nonzero failure rate. Also included is the "other" category for each subsystem. The failure rate failure mode analysis from which these rates were computed is presented in Appendix III.

In the analysis of the M&R Program data the secondary failure rates were negligible, accounting for less than 1% of the total primary and secondary failure rates. The secondary failure rates and causes were reported as follows:

- 29×10^{-6} failures per flight hour — AH-1G Tail Rotor Drive Subsystem - T/R D/S hanger assembly seal melted, coming apart due to heat/vibration from a blower failure.
- 102×10^{-6} failures per flight hour — AH-1G Tail Rotor Drive Subsystem - 90-degree gearbox lost in flight; tail rotor hub failure was suspected.
- 13×10^{-6} failures per flight hour — UH-1D/H Tail Rotor Control Subsystem - T/R pitch change link nut frozen due to bolt corrosion

The most significant inherent and induced failure modes identified for each subsystem are:

<u>T/R Hub and Blade Subsystem</u>

<u>Inherent</u> - AH-1G T/R grip bearings worn/loose/rough due to normal wear/lack of lubrication. Failure rate = 380×10^{-6} failures per flight hour.

<u>Induced</u> - UH-1C T/R blade damaged by armament debris. Failure rate = 2393×10^{-6} failures per flight hour.

<u>T/R Drive Subsystem</u>

<u>Inherent</u> - UH-1C T/R drive-shaft hanger bearing failure due to sandy environment/lack of lube. Failure rate = 494×10^{-6} failures per flight hour.

<u>Induced</u> - AH-1G 90-degree gearbox damaged internally due to T/R overload. Failure rate = 978×10^{-6} failures per flight hour.

TABLE XLII. FAILURE MODE ANALYSIS SUMMARY FOR THE UH-1D/H/C AND AH-1G TAIL ROTOR SYSTEM

(Based on M&R Data)

SUBSYSTEM Component	Number of Failures per Million Flight Hours					
	Type of Failure					All Failures
	Primary				Secondary	
	Inherent	Induced	Combat	Total		
MODEL UH-1D/H						
T/R HUB & BLADE	715	1480	64	2415	-	2415
T/R Hub	273	260	-	533	-	533
T/R Blade**	221	610	32	863	-	863
Other	*	*	*	156	-	156
T/R DRIVE	2728	1488	49	4265	-	4265
T/R Drive Shaft+	6	86	6	98	-	98
T/R Hanger Assembly++	494	129	-	623	-	623
42° Gearbox	324	143	13	480	-	480
90° Gearbox	392	313	-	-	-	705
Other	-	-	-	-	-	-
T/R CONTROLS	3010	1169	-	4400	13	4413
T/R Boot	-	324	-	324	-	324
T/R Slider	363	26	-	389	-	389
T/R Crosshead	26	234	-	260	-	260
Crosshead Bearing Set	207	78	-	285	-	285
T/R Pitch Change Link**	824	78	-	902	13	915
T/R Chain	519	-	-	519	-	519
T/R Quill	247	130	-	377	-	377
T/R Control Tube	-	221	-	221	-	221
Other	*	*	*	221	-	221
T/R SYSTEM TOTAL	6453	4137	113	11080	13	11093
MODEL UH-1C						
T/R HUB & BLADE	476	5346	-	6450	-	6450
T/R Hub	84	252	-	336	-	336
T/R Blade**	196	2547	-	2743	-	2743
Other	*	*	*	628	-	628
T/R DRIVE	2433	1287	30	3750	-	3750
T/R Drive Shaft+	39	33	6	78	-	78
T/R Hanger Assembly++	522	122	-	644	-	644
42° Gearbox	252	140	-	392	-	392
90° Gearbox	420	616	-	1036	-	1036
Other	-	-	-	-	-	-

TABLE XLII. (Continued)

SUBSYSTEM Component	Number of Failures per Million Flight Hours					
	Type of Failure					All Failures
	Primary				Secondary	
	Inherent	Induced	Combat	Total		
T/R CONTROLS	2183	476	-	3023	-	3023
T/R Boot	-	168	-	168	-	168
T/R Slider	979	-	-	979	-	979
T/R Crosshead	-	-	-	-	-	-
Crosshead Bearing Set	140	-	-	140	-	140
T/R Pitch Change Link**	406	112	-	518	-	518
T/R Chain	84	28	-	112	-	112
T/R Quill	168	28	-	196	-	196
T/R Control Tube	-	28	-	28	-	28
Other	*	*	*	364	-	364
T/R SYSTEM TOTAL	5092	7109	30	13223	-	13223
MODEL AH-1G						
T/R HUB & BLADE	875	1608	30	2625	-	2625
T/R Hub	585	146	-	731	-	731
T/R Blade**	145	731	15	891	-	891
Other	*	*	*	112	-	112
T/R DRIVE	2337	3317	89	5977	131	6108
T/R Drive Shaft+	-	245	12	257	-	257
T/R Hanger Assembly++	409	50	-	459	29	488
42° Gearbox	380	539	-	919	-	919
90° Gearbox	730	1403	29	2162	102	2264
Other	*	*	*	234	-	234
T/R CONTROLS	4363	1566	-	6148	-	6148
T/R boot	44	1036	-	1080	-	1080
T/R Slider	497	-	-	497	-	497
T/R Crosshead	160	234	-	394	-	394
Crosshead Bearing Set	204	-	-	204	-	204
T/R Pitch Change Link **	977	89	-	1066	-	1066
T/R Chain	730	15	-	745	-	745
T/R Quill	774	30	-	804	-	804
T/R Control Tube	-	73	-	73	-	73
Other	*	*	*	219	-	219
T/R SYSTEM TOTAL	7575	6491	119	14750	131	14881

* Primary failures falling in the "other" category were not divided among the subgroups--inherent, induced, and combat damage.
** Two per aircraft
+ Five per aircraft on UH-1C and AH-1G; six per aircraft on UH-1D/H
++ Three per aircraft on UH-1C and AH-1G; four per aircraft on UH-1D/H

T/R Control Subsystem

Inherent - UH-1C T/R slider worn due to normal wear, sandy environment. Failure rate = 979 x 10^{-6} failures per flight hour.

Induced - AH-1G T/R installation boot torn/cut due to rough handling, maintenance error. Failure rate = 1036 x 10^{-6} failures per flight hour.

11. MISHAP/ACCIDENT DATA ANALYSIS

11.1 MISHAP/ACCIDENT ANALYSIS APPROACH

The data analyzed were card records of mishaps reported on Army UH-1C/D/H and AH-1G helicopters. The data were obtained from the U.S. Army Board for Aviation Accident Research (USABAAR), currently called the U.S. Army Agency for Aviation Safety (USAAAVS).

The USAAAVS data are coded per AR385-40 [26] to identify the mishap classifications. These are defined, in part, by the repair time in maintenance manhours required to return an aircraft involved in a mishap to a serviceable condition. The following table presents the classes as defined for each model.

TABLE XLIII. MISHAP CLASSIFICATION DEFINITIONS

Mishap Class	UH-1C/D/H	AH-1G
1	Total Loss	Total Loss
2 (Major Damage)	Over 500 MMH	Over 800 MMH
3 (Minor Damage)	100-500 MMH	125-800 MMH
4 (Incident)	1-99 MMH	1-124 MMH
5 (Forced Landings)	No Damage	No Damage
6 (Precautionary Landing)	No Damage	No Damage

The first three of the six mishap classifications are designated as accident classifications.

The data coding permits the separate identification of material failure caused mishaps and mishaps from other (nonmaterial) causes. The coding also permits to a reasonable degree the identification of the helicopter subsystems and components which failed or were associated with the reported mishaps.

The period during which the data were collected is 1 January 1967 to 31 March 1971. The time bases which apply to this period are:

- UH-1C 1,250,000 flight hours
- UH-1D 4,050,000 flight hours
- UH-1H 5,450,000 flight hours
- AH-1G 949,000 flight hours
- UH-1C/D/H, AH-1G 11,699,000 flight hours

11.1.1 ALL MISHAPS (ANY-SYSTEM)

The first step in analyzing the accident data was an examination of all mishaps on file for aircraft Models AH-1G and UH-1C/D/H regardless of the systems involved (any-system). The number of

mishaps were counted and grouped according to model, cause (material or nonmaterial), and mishap class. The mishap rate per million flight hours λ_m for each group was determined by the following equation:

$$\lambda_m = \frac{n \times 10^6}{t} \tag{37}$$

where n = the number of mishaps

t = the time base

11.1.2 TAIL-ROTOR-ASSOCIATED MISHAPS

Tail-rotor-associated mishaps are those caused by a material failure within the tail rotor system or by nonmaterial causes affecting the tail rotor system. Nonmaterial causes include maintenance errors (tool left under drive shaft cover, lack of proper scheduled maintenance), and tail rotor contacts.

11.1.2.1 MATERIAL FAILURES

The data on mishaps resulting from material failures within the tail rotor system were divided into four groups, according to the failed component. They are:

- 42-degree gearbox
- 90-degree gearbox
- Tail rotor drive shafts and hangers
- Tail rotor hub and blade and pitch change mechanism

This grouping was determined by the USAAAVS method of coding data. The first three groups make up the tail rotor drive subsystem. The tail rotor hub and blade and the pitch change mechanism (tail rotor control) are grouped together in the data. Though some items in the last group may be definitely identified as part of one or the other subsystem, other parts such as bearings and nuts, bolts, washers, and similar items cannot be so identified, making it impossible to separate these two subsystems.

Within each component group, the data was further divided by failed item within the component and/or the failure mode. Failure modes are not always available because USAAAVS data defines the failure mode only in the narrative section of the mishap records, if at all. This information is not accessible without reading each narrative record. The quantity of data makes this approach impractical.

In Appendix III, a count of the material failures for each component and their mishap rates are presented in two sets of tables-- the first grouped by model and the second by mishap class.

11.1.2.2 NONMATERIAL FAILURES

The nonmaterial failure mishap records were separated into tail rotor contacts and other nonmaterial failures.

The tail rotor contacts consist of tail rotor strikes and tail rotor hits. A strike occurs when the tail rotor on a moving aircraft strikes a stationary object. When a foreign object hits or blows into the tail rotor, the incident is a hit.

The "other" nonmaterial failure mishaps are generally caused by carelessness on the part of maintenance personnel. Equation (37) was used to determine mishap rates.

11.1.2.3 EXTENT OF DAMAGE (REPAIR/REPLACEMENT COST)

In the USAAAVS data, the extent of damage in terms of repair or replacement cost in dollars is given for mishap classes 1, 2, 3, and 4. By definition classes 5 and 6 have no repair cost (see Table XLIII). For each aircraft model, mishap cause (material or nonmaterial) and mishap class the average cost of repair C was determined using the following equation:

$$C = \frac{\sum_{j=1}^{n} C_j}{n} \tag{38}$$

where C_j = the cost of the jth mishap

n = the number of mishaps with a known cost

11.2 MISHAP/ACCIDENT ANALYSIS RESULTS

11.2.1 ALL MISHAPS

Table XLIV presents a summary of all mishaps involving UH-1C/D/H and AH-1G aircraft. The mishap rates for the AH-1G aircraft are much higher than the same values for the UH-1 aircraft - particularly the material failure caused mishaps of classes 1 & 2 and 5 & 6, and nonmaterial failure mishaps of classes 5 & 6. The data includes AH-1G records from the time that aircraft was first delivered to the Army. The UH-1 Models

TABLE XLIV. SUMMARY OF ALL UH-1C/D/H AND AH-1G MISHAPS ON FILE

Model Time Base (flt hrs)	Mishap Class	Mishaps Due To: Material Failures No.	Material Failures λ_m *	Nonmaterial Causes No.	Nonmaterial Causes λ_m *	All Causes No.	All Causes λ_m *
UH-1C 1,250,000	1, 2	95	76.0	176	140.8	271	216.8
	3	4	3.2	13	10.4	17	13.6
	4	71	56.8	136	108.8	207	165.6
	5, 6	423	338.4	103	82.4	526	420.8
	All	593	474.4	428	342.4	1,021	816.8
UH-1D/H 9,500,000	1, 2	433	45.6	1,042	109.7	1,475	155.3
	3	17	1.8	72	7.6	89	9.4
	4	271	28.5	1,747	183.9	2,018	212.4
	5, 6	3,308	348.2	732	77.1	4,040	425.3
	All	4,029	424.1	3,593	378.2	7,622	802.3
AH-1G 949,000	1, 2	109	114.9	135	142.3	244	257.1
	3	2	2.1	10	10.5	12	12.6
	4	54	56.9	171	180.2	225	237.1
	5, 6	514	541.6	202	212.9	716	754.5
	All	679	715.5	518	545.8	1,197	1,261.3
ALL 11,699,000	1, 2	637	54.4	1,353	115.7	1,990	170.1
	3	23	2.0	95	8.1	118	10.1
	4	396	33.8	2,054	175.6	2,450	209.4
	5, 6	4,245	362.9	1,037	88.6	5,282	451.5
	All	5,301	453.1	4,539	388.0	9,840	841.1

* λ_m = Mishaps per million flight hours

had been in the field for four years before the data period began. Consequently, "infant mortality" type failures and forced and precautionary landings due to unfamiliarity with the aircraft are not included in the UH-1 data, but are included in AH-1G data.

11.2.2 Tail-Rotor-Associated Mishaps

The number of all tail-rotor-associated mishaps grouped by model, cause of mishap, and accident class are presented in Table XLV. The class 1 through 4 total is presented because all damage-causing mishaps fall in these classes.

11.2.2.1 Tail Rotor Strikes

All tail rotor contact mishaps fall in classes 1, 2, 3, and 4--thus all tail rotor contacts cause damage to the aircraft. Table XLVI presents the tail rotor strikes as a percentage of damage causing mishaps. It was noted that 50 percent of the class 1-4 mishaps involving troop carrying helicopters (UH-1D/H) are strikes, while strikes by the attack helicopter (UH-1C/AH-1G) comprise only 25 percent of the class 1-4 mishaps.

11.2.2.2 Extent of Damage

The extent of damage for tail rotor mishaps is presented in Tables XLVII through LI. An average dollar cost per mishap for each model, grouped by material, nonmaterial, and all causes and by mishap classification is given. The value presented is based on the number of mishaps with known cost (96 percent of all damage causing mishaps). The mishap rate per million flight hours is also presented. These values are used in the Cost Analysis section.

11.2.2.3 Material Failures

The material failures analysis for each tail rotor component consists of a list of the failed items within the component and the mode of failure, if known, and the number of occurrences for each failed item/mode grouped by aircraft model and by mishap class. The tables presenting the details of this analysis are in Appendix III. Table LII is a summary of the material failures analysis, presenting the number of mishaps (classes 1-6) and the number of accidents (classes 1-3) resulting from failures within the tail rotor system. The mishap rates are also presented.

From this data it can be seen that 61 percent of the accidents are caused by 90 degree gearbox and/or tail rotor separations, tail rotor hub failures, and suspected tail rotor failures, while the same modes account for only 29 percent of the mishaps.

TABLE XLV. SUMMARY OF TAIL-ROTOR-ASSOCIATED MISHAPS

MODEL Causes of Mishaps	Number of Mishaps In Mishap Class					
	1	2	3	4	1-4	All
UH-1C						
Material Failure Causes	8	6	1	8	23	40
Nonmaterial Causes	4	5	0	14	23	28
Contacts	3	5	0	9	17	17
Strikes	3	4	0	0	7	7
Hits	0	1	0	9	10	10
Other	1	0	0	5	6	11
ALL CAUSES	12	11	1	22	46	68
UH-1D						
Material Failure Causes	22	16	2	13	53	154
Nonmaterial Causes	22	53	11	73	159	185
Contacts	19	46	11	67	143	143
Strikes	19	43	8	42	112	112
Hits	0	3	3	25	31	31
Other	3	7	0	6	16	42
ALL CAUSES	44	69	13	86	212	339
UH-1H						
Material Failure Causes	23	32	1	21	77	144
Nonmaterial Causes	33	41	3	86	163	185
Contacts	28	36	1	84	149	149
Strikes	26	33	1	56	116	116
Hits	2	3	0	28	33	33
Other	5	5	2	2	14	36
ALL CAUSES	56	73	4	107	240	329
AH-1G						
Material Failure Causes	9	19	0	8	36	68
Nonmaterial Causes	3	11	0	13	27	41
Contacts	2	8	0	13	23	23
Strikes	2	8	0	10	20	20
Hits	0	0	0	3	3	3
Other	1	3	0	0	4	18
ALL CAUSES	12	30	0	21	63	109

TABLE XLV. (Cont'd)

MODEL Causes of Mishaps	Number of Mishaps In Mishap Class					
	1	2	3	4	1-4	All
ALL MODELS						
Material Failure Causes	62	73	4	50	189	406
Nonmaterial Causes	62	110	14	186	372	439
Contacts	52	95	12	173	332	332
Strikes	50	88	9	108	255	255
Hits	2	7	3	65	77	77
Other	10	15	2	13	40	107
ALL CAUSES	124	183	18	236	561	845

TABLE XLVI. TAIL ROTOR STRIKES AS A PERCENTAGE OF ALL DAMAGE-CAUSING TAIL ROTOR MISHAPS

Model	No. of Strikes	No. of Class 1-4 T/R Mishaps	%
UH-1C	7	46	15
UH-1D	112	212	53
UH-1H	116	240	48
AH-1G	20	63	32
UH-1C/AH-1G	27	109	25
UH-1D/H	228	452	50
All 4 Models	255	561	45

TABLE XLVII. AVERAGE REPAIR COSTS DUE TO TAIL-ROTOR-ASSOCIATED MISHAPS, MODEL UH-1C

Cause	Mishap Class	λ_m	No. With Known Cost	Average Cost
Material Failures	1	6.4	8	$ 218,425
	2	4.8	5	126,573
	3	0.8	1	16,898
	4	6.4	8	2,252
	5	8.0	10	-
	6	5.6	7	-
	1-4	18.4	22	109,781
	All	32.0	39	61,928
Non-material	1	3.2	4	219,348
	2	4.0	4	75,722
	3	0	0	-
	4	11.2	13	836
	5	1.6	2	-
	6	2.4	3	-
	1-4	18.4	21	56,721
	All	22.4	26	45,813
All Causes	1	9.6	12	218,733
	2	8.8	9	103,972
	3	0.8	1	16,898
	4	17.6	21	1,376
	5	9.6	12	-
	6	8.0	10	-
	1-4	36.8	43	83,868
	All	54.4	65	55,482

TABLE XLVIII. AVERAGE REPAIR COSTS DUE TO TAIL-ROTOR-ASSOCIATED MISHAPS, MODEL UH-1D

Cause	Mishap Class	λ_m	No. With Known Cost	Average Cost
Material Failures	1	5.4	22	$ 225,520
	2	4.0	15	78,754
	3	0.5	2	13,834
	4	3.2	12	3,055
	5	4.0	16	-
	6	21.0	85	-
	1-4	13.1	51	121,708
	All	38.0	152	40,836
Non-material	1	5.4	22	221,277
	2	13.1	50	67,341
	3	2.7	11	10,027
	4	18.0	70	3,631
	5	2.4	10	-
	6	4.0	16	-
	1-4	39.2	153	56,207
	All	45.6	179	48,043
All Causes	1	10.8	44	223,399
	2	17.1	65	69,975
	3	3.2	13	10,613
	4	21.2	82	3,547
	5	6.4	26	-
	6	25.0	101	-
	1-4	52.3	204	72,582
	All	83.6	331	44,733

TABLE XLIX. AVERAGE REPAIR COSTS DUE TO TAIL-ROTOR-ASSOCIATED MISHAPS, MODEL UH-1H

Cause	Mishap Class	λ_m	No. With Known Cost	Average Cost
Material Failures	1	4.2	22	$ 238,142
	2	5.9	29	152,958
	3	0.2	0	-
	4	3.8	21	7,857
	5	5.1	28	-
	6	7.2	39	-
	1-4	14.1	72	136,665
	All	26.4	139	70,791
Non-material	1	6.0	32	231,783
	2	7.5	41	104,686
	3	0.6	3	66,155
	4	15.8	85	3,493
	5	1.3	7	-
	6	2.7	15	-
	1-4	29.9	161	75,802
	All	33.9	183	66,690
All Causes	1	10.2	54	234,374
	2	13.4	70	124,684
	3	0.8	3	66,155
	4	19.6	106	4,354
	5	6.4	35	-
	6	9.9	54	-
	1-4	44.0	233	94,610
	All	60.3	322	68,460

TABLE L. AVERAGE REPAIR COSTS DUE TO TAIL-ROTOR-ASSOCIATED MISHAPS, MODEL AH-1G

Cause	Mishap Class	λ_m	No. With Known Cost	Average Cost
Material Failure	1	9.5	9	$ 394,558
	2	20.0	18	142,129
	3	0	0	-
	4	8.4	6	2,297
	5	6.3	6	-
	6	27.4	26	-
	1-4	37.9	33	185,549
	All	71.6	65	94,202
Non-material	1	3.2	3	356,489
	2	11.6	11	111,097
	3	0	0	-
	4	13.7	13	2,343
	5	7.4	7	-
	6	7.4	7	-
	1-4	28.5	27	85,999
	All	43.3	41	56,634
All Causes	1	12.7	12	385,041
	2	31.6	29	130,358
	3	0	0	-
	4	22.1	19	2,328
	5	13.7	13	-
	6	34.8	33	-
	1-4	66.4	60	140,752
	All	114.9	106	79,671

TABLE LI. AVERAGE REPAIR COSTS DUE TO TAIL-ROTOR-ASSOCIATED MISHAPS, MODELS AH-1G AND UH-1C/D/H

Class	Mishap Class	λm	No. With Known Cost	Average Cost
Material Failure	1	5.3	61	$ 254,082
	2	6.2	67	131,467
	3	0.4	3	14,855
	4	4.3	47	4,967
	5	5.1	60	-
	6	13.4	157	-
	1-4	16.2	178	138,120
	All	34.7	395	62,241
Non-material	1	5.3	61	233,312
	2	9.4	106	86,643
	3	1.2	14	22,055
	4	15.9	181	3,271
	5	2.2	26	-
	6	3.5	41	-
	1-4	31.8	362	67,174
	All	37.5	429	56,683
All Causes	1	10.6	122	243,696
	2	15.6	173	104,002
	3	0.6	17	20,784
	4	20.2	228	3,620
	5	7.3	86	-
	6	16.9	198	-
	1-4	48.0	540	90,560
	All	72.2	824	59,348

TABLE LII. SUMMARY OF TAIL ROTOR SYSTEM FAILURE MODES CAUSING MISHAPS

Subsystem / Component / Failure Mode	Mishap No.	Mishap λ_m	Accident No.	Accident λ_m
T/R Drive	231	19.75	63	5.38
42° Gearbox	25	2.14	4	0.34
42° Gearbox Failure	10	0.85	1	0.09
Other	15	1.29	3	0.25
90° Gearbox	101	8.63	28	2.39
90° Gearbox Failure	55	4.70	8	0.68
Gearbox Separation	22	1.88	18	1.54
Metal on Plug	8	0.68	-	-
Other	16	1.37	2	0.17
T/R Drive Shafts & Hangers	105	8.98	31	2.65
Hanger Bearing Failure	63	5.39	13	1.12
Coupling Failure	20	1.71	8	0.68
Other	22	1.88	10	0.85
T/R Hub and Blade and Pitch Change Mechanism	175	14.96	76	6.50
Suspect Tail Rotor Failure	47	4.02	31	2.65
Tail Rotor Hub Failure	30	2.57	19	1.62
Tail Rotor Yoke Failure	11	0.94	9	0.77
Tail Rotor Grip Failure	5	0.43	3	0.25
Tail Rotor Hub Failure	14	1.20	7	0.60
Tail Rotor and Gearbox Separation	21	1.79	17	1.45
Tail Rotor Bearing Failure	15	1.29	1	0.09
P/C/L Bearing	1	0.09	0	-
Thrust Bearing Failure	2	0.17	0	-
Crosshead Bearing Failure	3	0.26	0	-
Tail Rotor Bearing Failure	9	0.77	1	0.09
Control Rod Retaining Nut/ Cotter Key Failure	14	1.19	2	0.17
Control Quill Failure	8	0.68	1	0.09
Control Chain Twisted	10	0.85	-	-
Other	30	2.57	5	0.43
All Tail Rotor System Failures	406	34.71	139	11.89

These modes are the only ones which comprise a larger percentage of the accidents than of the mishaps.

11.2.3 Any-System Versus Tail-Rotor-Associated Mishaps

A comparison between the ratios of the number of accidents to the number of mishaps (accident probability) for mishaps, regardless of the aircraft system involved (any-system mishap) and for tail-rotor-associated mishaps is presented in Table LIII. Tail-rotor-associated occurrences result in accidents more frequently than do any-system occurrences. In the case of material failures, a tail rotor component failure is 2.7 times as likely to cause an accident as an any-system material failure.

The accident probability for tail rotor associated nonmaterial occurrences is 1.3 times the corresponding value for any-system occurrences. For all causes, the tail rotor system accident probability is 1.8 times the any-system accident probability.

TABLE LIII. TAIL-ROTOR-ASSOCIATED VERSUS ALL MISHAPS

	Number of Occurrences					
	Material Failures		Nonmaterial Failures		All Causes	
	Any	T/R	Any	T/R	Any	T/R
Mishaps (All Classes)	5301	406	4539	439	9840	845
Accidents (Classes 1-3)	660	139	1448	186	2108	325
Ratio of the Number of Accidents to the Number of Mishaps	.124	.342	.319	.423	.214	.385

12. COST ANALYSIS

The purpose of the cost analysis is to determine the total support cost of the UH-1/AH-1 tail rotor system. As can be observed in the preceding analyses there is considerable variation in the MTBF, MTR, MTBR, etc., for the components and in the fleet size and the use rate of the aircraft. These are all factors that are used in a cost analysis. This means that several separate analyses for each model under different use environments would be required. This would be very complex, difficult, if not impossible to establish, and not necessarily more useful than the following composite cost analyses for the utility and attack helicopter tail rotor systems.

12.1 COST ANALYSIS APPROACH

This cost analysis has been prepared by identifying each of the cost elements that comprise the total support cost of the UH-1D/H and AH-1G tail rotor system components.

12.1.1 Fleet Life-Cycle Consideration

To provide a basis for the analysis two fleet of aircraft are considered, one utility (UH-1D/H) and the other attack (AH-1G). Both are fleets of 1000 aircraft each having production deliveries of 40 aircraft per month over a 25-month period. The use rate of these aircraft is 70 flight hours per month per aircraft for the utility helicopter fleet and 60 flight hours per month per aircraft for the attack helicopter fleet. The useful life of the utility helicopters is 5000 flight hours and for the attack helicopters it is 3500 flight hours. This makes the total life-cycle equal to 5 million flight hours for the utility fleet and 3.5 million flight hours for the attack fleet. For the analysis it is assumed that the flight hours are accumulated for each fleet as shown by the curves on Figure 10.

12.1.2 Cost of the Tail Rotor System Delivered As Part of the Production Aircraft

A research made in several Departments at BHC revealed that no cost breakdown exists that proportions the air vehicle cost to its subsystems and components. To establish a value that could reasonably represent this element of the total tail rotor life, the following equation was used. In this equation the cost of the component as it is delivered is estimated to be 60 percent of the packaged spare component.

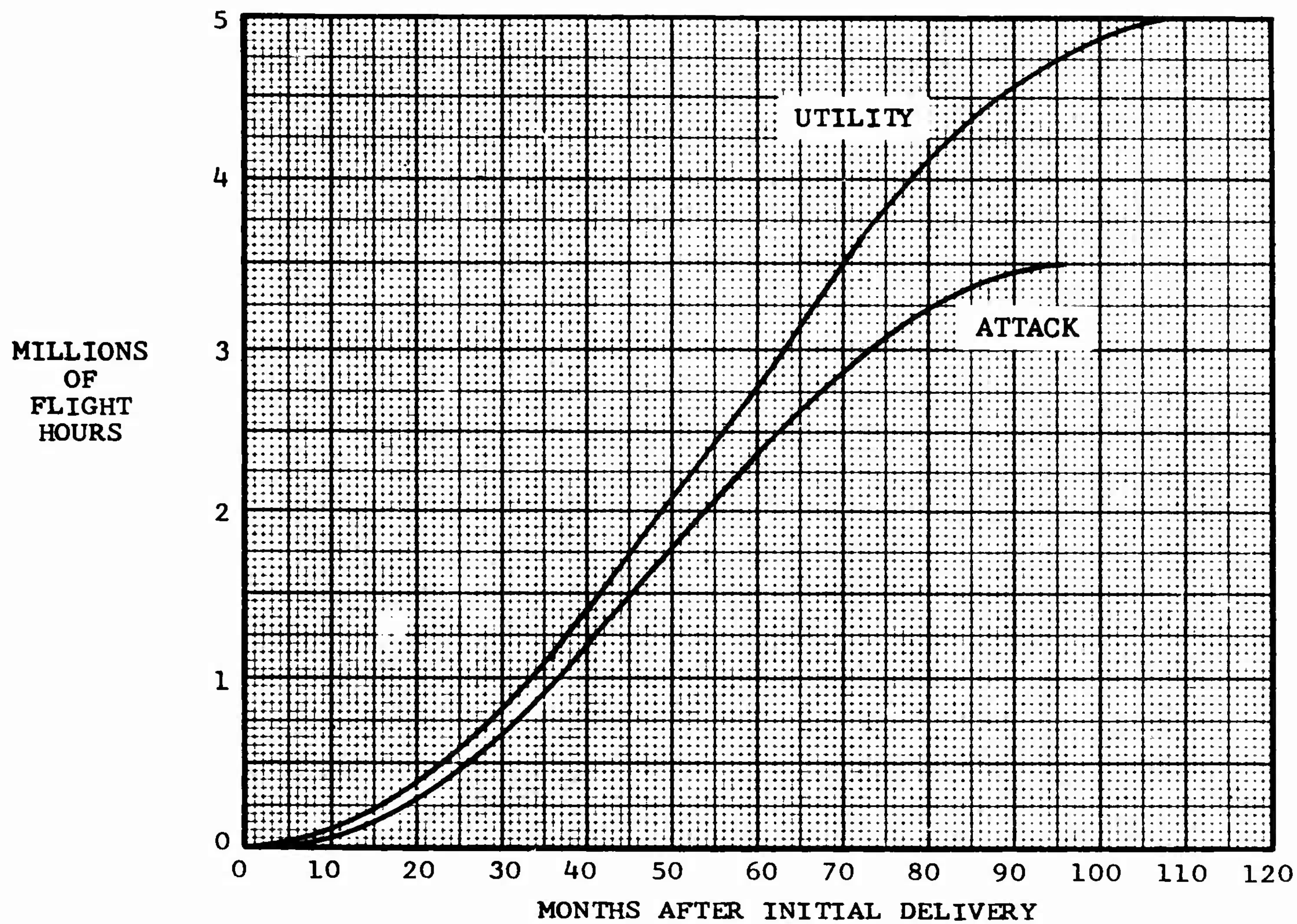


Figure 10. Flight Hours Accrued by the Fleet of Aircraft.

$$C_I = 0.60m\sum_{i=1}^{n} k_i C_i \qquad (39)$$

where C_I = the total estimated cost of the tail rotor systems delivered on the production aircraft

m = the number of production aircraft in the fleet

C_i = the dollar cost of the ith spare component

k_i = the number of i components installed per aircraft

n = the number of different components in the aircraft tail rotor system

The spare parts dollar costs used in the analysis are those shown in Table LIV which were established from the sources referenced.

12.1.3 Number of Spares Required

The number of spares required for parts that are normally scrapped when they are removed from the aircraft for failure is determined by dividing the model's life-cycle flight hours by the MTBF of the component. The number of replacement items required where the parts are either limited-life items or overhaul items is determined by dividing the model's life-cycle flight hours by the MTBR" computed for the component in Appendix VI.

To establish a logistic pool of replacement parts for the two types of parts, the total flight hours to be accrued during the first 21 months after the initial production delivery is divided by the MTBF and MTBR" values as appropriate.

To determined, for the number of overhaulable items, the replacements that are spare assemblies and those that are overhauled, the number of replacements are multiplied by the fraction of items that are scrapped. The result is the number of spare assemblies that are required. It is assumed that the remainder are overhauled.

Where it was determined from the data that the control quill assembly was frequently repaired by replacing the sprocket, the number of spare items for each of these items has been appropriately adjusted.

TABLE LIV. TAIL ROTOR SYSTEM COMPONENT REPLACEMENT COSTS

SUBSYSTEM Components	Bell Part Number	Spares Cost Dollars	Cost Source *	Dollar Cost Used In Analysis	Dollar Cost For Overhaul *G
T/R HUB & BLADE					
Hub Assembly	204-011-701-019	500.79	C		
	204-011-801-003	517.41	D		
	204-011-801-005	565.66	A		
	204-011-801-009	815.15	E	815	
	204-011-801-011	854.02	B		
	209-010-701-003	461.86	E		
T/R Blade	204-011-702-015	303.28	E	348	
	204-011-702-017	347.52	E		
T/R DRIVE					
T/R Drive Shaft	204-040-620-003	153.93	E	154	
	204-040-620-005	114.78	E	115	
	209-040-611-001	189.39	A		
Hanger Assembly	204-040-600-007	180.73	A	172	48
	204-040-600-009	172.27	C		
42° Gearbox	204-040-003-037	1242.21	C	1242	286
90° Gearbox	204-040-012-013	1534.35	D	1534	408
T/R CONTROL					
Chain	204-001-739-003	53.00	D	53	
Quill Assembly	204-010-740-005	48.29	E	48	
Sprocket Wheel	204-010-768-001	5.81	E	6	
Control Tube	204-010-742-009	18.93	E	19	
Cone Set	204-010-724-005	3.01	D	3	

TABLE LIV. (Cont'd)

SUBSYSTEM Components	Bell Part Number	Spares Cost Dollars	Cost Source *	Dollar Cost Used In Analysis	Dollar Cost For Overhaul *G
T/R CONTROL (Cont'd)					
Static Stop	204-010-774-011	9.26	E	9	
Nut	204-010-719-001	15.88	E	16	
Boot	47-641-101-001	3.65	F	4	
Slider	204-010-720-003	45.14	E	42	
	204-010-720-007	41.34	E		
Plate	204-010-721-003	.90	E	1	
Bearing Set	204-011-761-003	6.16	A		
	204-011-769-001	11.47	D	12	
Crosshead	204-011-711-001	12.25	E	12	
Pitch Change Link	204-011-762-001	22.28	D	24	
	204-011-762-005	23.16	C		
	204-011-762-007	20.82	B		
	204-011-762-011	27.53	E		

* COST SOURCE

Bell Helicopter Company UH-1 Series Target Price List No.
No. 3 DAAJ01-67-A-0014 -A
No. 4 DAAJ01-68-A-0022 -B
No. 5 DAAJ01-69-A-0314 -C
No. 6 DAAJ01-69-A-0314 -D
No. 8 DAAJ01-72-A-0012 -E

Cost Source F - the current procedure specified for spares pricing by Contract DAAJ01-72-A-0012

Cost Source G - RAMMIT Major Item Special Studies on the individual components

12.1.4 Cost of the Spare Parts Required

The cost of the spare parts C_{SP} required was obtained by multiplying the number of parts required of each type by the cost established for it on Table LIV. The part costs used are the costs that are typical for the greater percentage of components installed.

Although the UH-1D/H has two types of tail rotor drive shafts installed, five -3 and one -5 assemblies, the failure rate and maintenance man-hour data do not distinguish between the two types of assemblies. The DA form 2407 data indicate that the -5 assembly's replacement rate is lower than that of the -3. For this reason no attempt has been made in the cost analysis of the utility helicopter's tail rotor system to differentiate between the two except in the initial production delivered on-board systems. The cost used in the analysis is that shown for the -3.

12.1.5 Cost of the Overhauled Assemblies

Separate costs were computed for the three assemblies that are overhauled: the 42- and 90-degree gearboxes, and the tail rotor drive-shaft hanger assemblies. A review of the different overhaul contracts showed considerable variation in the overhaul costs for these components, although they were generally consistent with the overhaul costs contained in the RAMMIT Major Item Special Study (MISS) reports,[13 thru 19] which are shown on Table LIV and are used in this analysis.

The overhaul costs, C_{OH}, were computed by multiplying the number of component overhauls by the overhaul cost per unit.

The analysis may contain a degree of duplication in that the intermediate maintenance man-hours for the hanger assembly probably include a mixture of overhauls and repairs. The cost analysis treats this maintenance as if it were all repairs.

12.1.6 Transportation Costs

The transportation costs to be considered in the tail rotor system are:

a. Cost of moving spare parts from the factory to the Army's main distribution center (Red River Army Depot-182 miles)

b. Cost of moving overhaul components from the distribution center to the factory (or depot maintenance area) and back to the distribution center

c. Cost of moving both spare parts and overhaul parts between the distribution center and

- bases within the United States
- bases overseas

Costs in moving the production helicopters from the factory to the use locations are not considered.

Three methods of transportation are included:

a. Ground (truck) transportation

b. Transportation by air

c. Transportation by cargo vessel

For this analysis the aircraft are considered to be stationed

- 20 percent in the United States at an average distance of 1500 miles from the distribution center; transportation of parts is accomplished by ground transportation

- 80 percent overseas where 25 percent of the overseas spare and overhaul components are transported to the location by air and the remainder are transported by cargo vessel. It is assumed that all assemblies for overhaul are returned to the United States by cargo vessel.

Based on cost information obtained from the Spares Engineering Department at BHC, components of the size and density of those that make up the tail rotor system can be shipped by truck at a cost of 0.15 dollar per ton-mile. The cost of air transportation which will vary considerably depending on the distance has been estimated at 600 dollars per ton. Similarly, the cost for cargo shipment has been estimated at 300 dollars per ton.

The total cost C_{TR} for transportation of spares and overhaul components is determined using the following equations

$$C_1 = (W_s + 2W_o)\ D \times R_T \qquad (40)$$

where C_1 = the dollar cost of moving parts and overhaul assemblies between the factory and the distribution center

W_s = the total weight in tons of the spare components

W_o = the total weight in tons of the overhauled components

D = the distance to be hauled by the truck

R_T = the cost rate per ton-mile to move the items by truck

$$C_2 = P_1(W_s + 2W_o)\ D \times R_T \tag{41}$$

where C_2 = the dollar cost of moving parts and overhaul assemblies between the distribution center and base locations within the US

P_1 = the fraction of the components to be shipped to the US locations

$$C_3 = P_2(W_s + W_o)R_A \tag{42}$$

where C_3 = the dollar cost of moving the items between the distribution center and overseas locations by air

P_2 = the fraction of items to be airshipped

R_A = the cost per ton to move the items by air

$$C_4 = \left[(1 - P_1 - P_2)(W_s + 2W_o) + P_2(W_o)\right] R_C \tag{43}$$

where C_4 = the dollar cost of moving the items between the distribution center and overseas locations by cargo vessel

R_C = the cost per ton to move the items by cargo vessel

$$C_{TR} = C_1 + C_2 + C_3 + C_4 \tag{44}$$

12.1.7 Maintenance Costs

The maintenance cost per flight hour to support the tail rotor system was obtained by multiplying the total organizational and intermediate maintenance man-hours per flight hours by 16.50 dollars. This man-hours cost was obtained from RAMMIT MISS reports,[7 thru 19] and it represents their best estimate of the current average direct and indirect cost for maintenance man-hours expended at each maintenance level. The depot maintenance cost was not computed since this cost should be included in the component overhaul cost. The total life-cycle cost value for tail rotor system maintenance C_{MN} was computed by multiplying the cost per flight hour by 5 million flight hours for the utility helicopter and 3.5 million flight hours for the attack helicopter.

12.1.8 Cost of Tail Rotor System Related Mishaps

The cost of tail rotor related mishaps was determined by: first separately obtaining the mishap rate for each mishap classification for UH-1D/H and the AH-1G from Section 11; next, the cost of the total loss mishaps, Class 1, was obtained by taking the highest costs observed in the USAAAVS accident data for Class 1 mishaps, as shown on Table LV, and rounding the result to 245,000 dollars for the utility helicopter and 475,000 dollars for the attack helicopter; and finally, the average cost of Classes 2, 3, and 4 repairable mishap damage was obtained for the UH-1D/H and AH-1G from Section 11.

These factors were then inserted in the following equation.

$$C_A = (\lambda_I \times C_I + \lambda_{II} C_{II} + \lambda_{III} C_{III} + \lambda_{IV} C_{IV}) mT \qquad (45)$$

where

C_A = the total life cycle cost in dollars for tail rotor associated mishaps

$\lambda_I, \lambda_{II}, \lambda_{III}, \lambda_{IV}$ = the mishap rate in occurrences per flight hour for Class 1, 2, 3, and 4 mishaps, respectively

$C_I, C_{II}, C_{III}, C_{IV}$ = the average dollar cost used for Class 1, 2, 3, and 4 mishaps respectively

m = the number of aircraft in the fleet

T = the total expected life for each aircraft

TABLE LV. AIRCRAFT TOTAL LOSS COST VS DATE, PER USAAAVS MISHAP RECORDS

Accident Date Yr/Mo	Aircraft Model			
	UH-1C	UH-1D	UH-1H	AH-1G
67/01	219,911	288,554	-	-
67/02	217,679	228,554	-	-
67/07	217,679	228,554	228,554	318,707
68/09	216,914	228,554	228,554	318,707
69/07	216,914	237,504	228,554	451,141
69/08	216,914	237,504	244,345	451,141
69/09	224,415	237,504	244,345	451,141
70/04	224,415	237,504	244,345	456,401
70/05	224,415	237,504	244,345	471,630
71/03	224,415	237,504	244,345	471,630

12.1.9 Total Tail Rotor System Life-Cycle Costs

The estimate of the total tail rotor system life-cycle costs, C_T, is obtained by summing each of the cost factors.

$$C_T = C_I + C_{SP} \; C_{OH} + C_{TR} + C_{MN} + C_A \qquad (46)$$

where the terms are as previously defined.

12.2 COST ANALYSIS RESULTS

Each of the elements which comprise the total support cost is presented separately. These elements are then combined to obtain the total cost estimate. Many of the constants within the analysis are established as such by the constraints of fleet size, rate of delivery, use rate, spares cost, etc.

These constants are actually variables for which different values can be established with a different set of constraints. There was insufficient time to evaluate the sensitivity of changes to these values.

12.2.1 Initial Cost of the Tail Rotor System as Delivered on Production Aircraft

The following is the estimated cost of the initial tail rotor installation delivered on the production aircraft

- Utility Helicopter

  3,679.80 Dollars For One Ship Set
  3,679,800 Dollars For a 1000 Aircraft Fleet
  0.73596 Dollar/Flight hour

- Attack Helicopter

  3,507.60 Dollars For One Ship Set
  3,507,600 Dollars For a 1000 Aircraft Fleet
  1.00217 Dollars/Flight Hour

While the utility helicopter's cost per ship set is higher due to the additional driveshaft and hanger assembly, the cost per flight hour is greater for the attack helicopter fleet which has a lower number of flight hours in its life cycle.

12.2.2 Spare Parts Cost

Tables LVI and LVII show the estimated number of spare parts that would be required to support fleets of utility and attack aircraft through their life cycles based on the component MTBF, MTBR, TBO and retirement lives.

These tables also show the estimated number of spare assemblies in addition to those required for scheduled and unscheduled replacement to maintain an adequate supply system. This estimate is based on:

a. A use rate of 70 hours per month for the utility aircraft and 60 hours per month for the attack helicopter

b. Deliveries of production helicopters at a rate of 25 aircraft per month

c. Spare components for replacements of failed items during the first 21 months being established as a logistics pool of components.

TABLE LVI. SPARE PARTS REQUIREMENTS FOR A FLEET OF UTILITY AIRCRAFT DELIVERED AT A RATE OF 25 AIRCRAFT PER MONTH

SUBSYSTEM / Component	No. Per A/C	Scrap %	Spares Required for Part Replacement	Spares Required for Logistics Pool*	Total Spares Required	Total Spares Cost (Dollars)
T/R HUB & BLADE						14,120,385
T/R Hub	1	100.0	9,026	697	9,723	7,924,245
T/R Blade	2	100.0	16,529	1,276	17,805	6,196,140
T/R DRIVE						2,735,054
T/R Drive Shaft	6	100.0	2,832	227	3,059	471,086
42° Gearbox	1	5.1	300	453	753	935,226
90° Gearbox	1	2.2	152	533	685	1,050,790
Hanger Assy	4	0.5	152	1,464	1,616	277,952
T/R CONTROL						566,146
Chain	1	100.0	2,595	200	2,795	148,135
Quill Assy	1	100.0	227	145	372	17,856
Sprocket Wheel	1	100.0	1,659	128	1,787	10,722
Control Tube	1	100.0	1,105	86	1,191	22,629
Cone Set	1	100.0	-	-	-	-
Static Stop	1	100.0	-	-	-	-
Nut	1	100.0	-	-	-	-
Boot	1	100.0	1,620	126	1,746	6,984
Slider	1	100.0	1,945	151	2,096	88,032
Plate	1	100.0	-	-	-	-
Bearing Set	1	100.0	1,426	110	1,536	18,432
Crosshead	1	100.0	1,300	101	1,401	16,812
Pitch Change Link	2	100.0	9,150	706	9,856	236,544
TAIL ROTOR SYSTEM			Total Cost			17,421,585
			Cost/Flight Hour			[illegible].4843

*Based on the first 21 months' accrued flight hours (385,875)

TABLE LVII. SPARE PARTS REQUIREMENTS FOR A FLEET OF ATTACK HELICOPTERS DELIVERED AT A RATE OF 25 AIRCRAFT PER MONTH

SUBSYSTEM Component	No. Per A/C	Scrap %	Spares Required for Part Replacement	Spares Required for Logistics Pool*	Total Spares Required	Total Spares Cost (Dollars)
T/R HUB & BLADE						13,327,747
T/R Hub	1	100.0	8,951	846	9,797	7,984,555
T/R Blade	2	100.0	14,028	1,326	15,354	5,343,192
T/R DRIVE						2,810,186
T/R Drive Shaft	5	100.0	4,408	425	4,833	744,282
42° Gearbox	1	4.3	213	468	681	845,802
90° Gearbox	1	1.9	104	515	619	949,546
Hanger Assy	3	0.7	109	1,464	1,573	270,556
T/R CONTROL						511,552
Chain	1	100.0	2,608	247	2,855	151,315
Quill Assy	1	100.0	85	266	351	16,848
Sprocket Wheel	1	100.0	2,730	258	2,988	17,928
Control Tube	1	100.0	256	25	281	5,339
Cone Set	1	100.0	-	-	-	-
Static Stop	1	100.0	-	-	-	-
Nut	1	100.0	-	-	-	-
Boot	1	100.0	3,780	358	4,138	16,552
Slider	1	100.0	1,740	165	1,905	80,010
Plate	1	100.0	-	-	-	-
Bearing Set	1	100.0	714	68	782	9,384
Crosshead	1	100.0	1,379	131	1,510	18,120
Pitch Change Link	2	100.0	7,463	706	8,169	195,056
TAIL ROTOR SYSTEM			Total Cost			16,649,485
			Cost/Flight Hour			4.7570

*Based on 21 months' accrued flight hours (330,750)

Finally, Tables LVI and LVII show the estimated spare-part life-cycle cost required to support the tail rotor systems of the two aircraft fleets. Here again, the utility fleet has a larger total cost (5 percent) than the attack fleet, while the cost per flight hour for the attack fleet is larger (37 percent) than the similar cost for the utility fleet. Once again, the difference is primarily due to the difference in total fleet life-cycle flight hours.

12.2.3 Overhaul Costs

Table LVIII shows that the cost to perform the overhaul of tail rotor system components during the life cycle of the utility fleet of aircraft is about 30 percent greater than the similar cost for the attack fleet. This is primarily due to the larger number of hanger assemblies on the utility helicopter and difference in total life-cycle flight hours. The overhaul cost per flight hour for the attack fleet is only about 10 percent larger than the similar cost for the utility fleet.

TABLE LVIII. OVERHAUL COSTS

Assembly	Utility Helicopter		Attack Helicopter	
	Number of O/H	Overhaul Cost - Dollars	Number of O/H	Overhaul Cost - Dollars
42° Gearbox	5,569	1,592,734	4,738	1,355,068
90° Gearbox	6,745	2,751,960	5,340	2,178,720
Hanger Assembly	25,197	1,209,456	15,377	738,096
TOTAL COST		5,554,150		4,271,884
COST/FLIGHT HOUR		1.1108		1.2205

12.2.4 Transportation Cost To Move the Spare and Overhaul Components

Table LIX shows the weight of the spare parts and overhaul assemblies to be transported between the factory, the distribution center, and the using location. Using the cost factors, the part distribution ratios, and the assumptions and equations presented in 12.1.6, the following estimate of transportation costs of tail rotor system components was determined.

- Utility Helicopter

  296,072 Dollars for the Life Cycle of a 1000-Aircraft Fleet

  0.0592 Dollar/Flight Hour

- Attack Helicopter

  246,068 Dollars for the Life Cycle of a 1000-Aircraft Fleet

  0.0703 Dollar/Flight Hour

12.2.5 Maintenance Support Costs

The costs for the tail rotor system organizational, direct support, and general support maintenance man-hours per flight hour were estimated using MMH/FH values from Section 9 and man-hour direct/indirect costs from RAMMIT MISS reports. The resulting fleet life-cycle cost and the cost per flight hour for this element are:

- Utility Helicopter

  9,333,500 Dollars Total
  1.8667 Dollars/Flight Hour

- Attack Helicopter

  4,709,950 Dollars Total
  1.3457 Dollars/Flight Hour

Here, both the total life-cycle cost and the cost per flight hour for this cost element are greater for the utility aircraft than they are for the attack aircraft. This difference is due to the large difference in maintenance man-hours per flight hour observed for the two types of aircraft in the Navy 3-M data (see Section 9).

TABLE LIX. PARTS SHIPPING WEIGHTS

SUBSYSTEM Component	Component Shipping Weight (Pounds)	Total Weight			
		Spares		O/H Assemblies	
		Utility	Attack	Utility	Attack
T/R HUB & BLADE					
T/R Hub	19.0	184,737	186,143	-	-
T/R Blade	10.0	178,050	153,540	-	-
T/R DRIVE					
T/R Drive Shaft	6.0	18,354	28,998	-	-
42° Gearbox	32.0	24,096	21,792	178,208	151,616
90° Gearbox	50.0	34,250	30,950	337,250	267,000
Hanger Assy	4.0	6,464	6,292	100,788	61,508
T/R CONTROLS					
Chain	0.6	1,677	1,713	-	-
Quill Assy	1.0	372	351	-	-
Sprocket Wheel	0.4	715	1,195	-	-
Control Tube	0.6	715	169	-	-
Cone Set	0.1	-	-	-	-
Static Stop	0.4	-	-	-	-
Nut	0.2	-	-	-	-
Boot	0.5	873	2,069	-	-
Slider	0.3	628	572	-	-
Plate	0.2	-	-	-	-
Bearing Set	0.5	768	391	-	-
Crosshead	0.5	700	755	-	-
Pitch Change Link	0.5	4,928	4,084	-	-
TOTAL WEIGHT		457,327	439,014	616,246	480,124
Utility Helicopter			1,073,573		
Attack Helicopter			919,138		

12.2.6 Costs of Tail Rotor System Related Mishaps

During the life of the aircraft fleet, tail-rotor-associated Class 1 mishaps would result in the loss of:

Utility	52 aircraft
Attack	44 aircraft

The dollar loss due to the tail-rotor-associated Class 1 mishaps is:

Utility	12,740,000 Dollars
Attack	20,900,000 Dollars

During the life of the aircraft fleet, tail-rotor-associated mishaps of Class 2, 3, and 4 could be expected to occur the following number of times with the resulting estimated dollar cost:

Utility	76 Class 2 mishaps for 7,455,600-dollar loss
	13 Class 3 mishaps for 307,866-dollar loss
	101 Class 4 mishaps for 403,394-dollar loss
Attack	126 Class 2 mishaps for 16,425,108-dollar loss
	0 Class 3 mishaps for zero-dollar loss
	77 Class 4 mishaps for 179,256-dollar loss

12.2.7 Total Tail Rotor System Life-Cycle Cost

The total life-cycle cost of the two fleets of aircraft, utility helicopters and attack helicopters, was estimated by summing each of the cost elements described above. The resulting dollar cost per flight hour was also computed. Table LX summarizes the results of this analysis.

Discounting the cost of tail-rotor-system-associated accidents, the dollar cost per flight hour for the attack helicopter is 116 percent of the cost rate for the utility helicopter. However, when considering the tail-rotor-system-associated accidents, the dollar cost per flight hour for the attack helicopter is almost 167 percent of the cost rate for the utility helicopter.

TABLE LX. TAIL ROTOR SYSTEM LIFE-CYCLE COST SUMMARY

Cost Element	Utility Helicopter				Attack Helicopter			
	Dollar Cost/ Fleet	Dollar Cost/ Flt Hr	% of Cost Subtotal	% of Total Costs	Dollar Cost/ Fleet	Dollar Cost/ Flt Hr	% of Cost Subtotal	% of Total Costs
Cost of T/R System Delivered on the Production Aircraft	3,679,800	0.7360	10.2	6.43	3,507,600	1.0022	11.9	5.24
Spare Parts Cost	17,421,585	3.4843	48.0	30.46	16,649,485	4.7570	56.7	24.89
Component Overhaul Costs	5,554,150	1.1108	15.3	9.71	4,271,884	1.2205	14.5	6.39
Component Transportation Costs	296,072	0.0592	0.8	0.52	246,068	0.0703	0.9	0.37
Maintenance Cost	9,333,500	1.8667	25.7	16.32	4,709,950	1.3457	16.0	7.04
Cost Subtotal	36,285,107	7.2570	100.0	63.44	29,384,987	8.3957	100.0	43.93
Cost of T/R System Associated Accidents	20,906,860	4.1814	57.6	36.56	37,504,364	10.7155	127.6	56.07
Total Cost	57,191,967	11.4384	157.6	100.00	66,889,351	19.1112	227.6	100.00

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GLOSSARY

Accident, Army Aircraft	An Army aircraft mishap resulting in total loss of the aircraft or damage to the aircraft requiring greater than 99 man-hours to repair for the UH-1C/D/H or greater than 124 man-hours to repair for the AH-1G.
Any-System	A term used to refer to all mishaps, regardless of the system involved.
Contact	A term which refers to a group of non-material tail rotor associated mishaps which are either tail rotor strikes or tail rotor hits.
EMT	The elapsed maintenance time expressed in calendar hours.
Hit	A term that refers to tail rotor contacts which involve a foreign object hitting or blowing into the tail rotor.
$\bar{M}$	Mean corrective and preventive action time. This is the mean active downtime resulting from both corrective and preventive maintenance expressed in calendar hours.
$\bar{M}_C$	$\bar{M}$ for a specified component C.
$\bar{M}_S$	$\bar{M}$ for a specified system S.
$\bar{M}_{SS}$	$\bar{M}$ for a specified subsystem SS.
$\bar{M}_{pt}$	Mean preventive maintenance action time. This is the statistical mean of the sum of the times required for preventive actions divided by the number of these actions scheduled for a given period expressed in calendar hours.
$\bar{M}_{pt_C}$	The mean preventive maintenance action time for the component C.
$\bar{M}_{pt_S}$	The mean preventive maintenance action time for the system S.
$\bar{M}_{pt_{SS}}$	The mean preventive maintenance action time for the subsystem SS.

MAOT	The maximum allowable operating time to retirement or between overhauls.
MIRF	Major Item Removal Frequency, one of the RAMMIT analyses containing component histogram tables of accumulated operating time at removal and coded reasons for removal of major aircraft components. It presents separate tables for first removals of new items and first removals of items with one prior overhaul.
Mishap, Army Aircraft	An unplanned event involving one or more Army aircraft, occurring between the time the engine(s) is(are) started for the purpose of commencing flight until the time the aircraft comes to rest with all engines and propellers or rotors stopped and brakes set or wheel chock in place, which may or may not result in damage to the aircraft. This excludes any action by enemy or hostile forces.
Mishap, Tail-Rotor-Associated	A mishap caused by a material failure within the tail rotor system or by a nonmaterial cause affecting the tail rotor system. The nonmaterial causes include maintenance errors and tail rotor contacts.
$\overline{MM}$	The average number of maintenance men required to perform a maintenance task.
MMH	Maintenance man-hours.
MMH/FH	Maintenance man-hours per flight hour. This is the average number of man-hours required per flight hour to perform the maintenance (scheduled and unscheduled) required to support a specified item.
MOS	Military occupational specialty. The MOS numbers of military personnel indicate their occupations and skill levels.
MOS 67N20	A UH-1C/D/H helicopter repairman.
MOS 67Y20	An AH-1G helicopter repairman.
MOS 68D20	An aircraft powertrain repairman.
MOS 68E20	An aircraft rotor and propeller repairman.

MTBF	Mean-time-between-failures. The sum of the operating times accumulated on all items of a given type divided by the number of failures of that item, where a failure is defined as any occurrence requiring unscheduled maintenance.
MTBM	The mean-time-between-maintenance for all maintenance actions (scheduled and unscheduled) expressed in flight hours.
MTBR	Mean-time-between-removals. The average interval in hours between maintenance actions resulting in the removal of an item from a fleet of aircraft.
MTBR'	An estimated MTBR computed from RAMMIT MIRF data which considers only failures and time change removals but includes a group of components which had failed once and had been repaired.
MTBR"	An estimated MTBR computed from RAMMIT MIRF data which considers only failures and time change removals but includes a group of components which had failed once and had been repaired and a second group which had failed twice and had been repaired twice.
$MTBR_e$	An estimated MTBR computed from RAMMIT MIRF data which considers only failures and time change removal causes.
$MTBR_h$	The mean-time-between-removals of the component for removal cause h.
MTBSM	Mean-time-between-scheduled-maintenance.
MTR	Mean-time-to-removal. The average of the component operating times at removal from the aircraft. The component operating time is the time since new and/or time since last overhaul, expressed in flight hours.
MTR_F	The mean-time-to-removal for the assemblies removed for failure causes.

MTR_{NF}	The mean-time-to-removal for the assemblies removed for nonfailure causes (includes both nonfailure and scheduled maintenance (nontime change) coded removal causes).
MTR_T	The item's mean-time-to-removal for all causes.
MTTR	The average downtime in calendar hours for a specified unscheduled task.
$MTTR_A$	The MTTR for a specific repair action A on like items.
$MTTR_C$	MTTR for a specified component C.
$MTTR_S$	MTTR for a specified system S.
$MTTR_{SS}$	MTTR for a specified subsystem SS.
RAMMIT	Reliability and Maintainability Management Improvement Techniques. A TAMMS data analysis activity conducted by the Product Assurance Directorate of the Army Aviation Systems Command, St. Louis, Missouri.
Strike	A term that refers to tail rotor contacts which occur when the tail rotor of a moving aircraft strikes a stationary object.
T_C	The specified retirement life or life at removal for overhaul (TBO).
TAMMS	The Army Maintenance Management System described in Department of the Army Technical Manual TM 38-750.
TBO	The MAOT between overhauls.

APPENDIX I

MAINTENANCE PROCEDURES

The maintenance procedures appearing in this appendix were extracted from the Army Technical Manuals on organizational level maintenance for Models UH-1C/D/H and AH-1G.[1,2,3] The procedures included are those relating to the tail rotor system as defined in this report. They are presented in the following order:

MAINTENANCE PROCEDURES

TAIL ROTOR HUB AND BLADE ASSY

Model UH-1D/H

A. Removal

1. Disconnect pitch change link from each tail rotor blade grip pitch horn by removing nut, bolt, and washers. Keep safety washer, steel washer, and other attaching parts with link.

2. Remove crosshead and shim by removing two attaching bolts with nuts and washers.

3. Cut lockwire wrapped on each end of boot.

4. Remove cotter pin, nut, and washer from end of pitch change rod. Remove bearing set, retainer plate, and pitch change slider. Remove boot.

5. Cut lockwire and remove hub retainer nut. Remove static stop and shim, if existing.

6. Move tail rotor hub (and blade assembly) outboard on splines of shaft, and remove split cone set as it is released. Remove tail rotor over end of gearbox shaft and pitch change rod.

NOTE

Fasten split cones together and retain as a matched set.

B. Inspection

1. Inspect all tail rotor parts for evidence of damage.

2. Inspect moving parts and pivot bolts in the pitch change mechanism for looseness, wear, and play. Use a dial indicator to measure axial and radial play in the pitch link bearings.

3. Inspect for excessive movement between blade grip and the hub on each blade as follows:

   a. Rigidly support the rotor at hub yoke to eliminate any possibility of movement. (The blades and grips must be free.)

b. Free play check. With fingertips, move leading edge of blade away from center just enough to take out play. Do not use force. Measure total movement. Release and allow blade to return to center. Move trailing edge away from center and measure in the same manner. Maximum movement allowed: 0.25 inch each side. Repeat procedure on opposite blade.

c. Maximum deflection check. Pull leading edge of blade away from center with 4 to 5 pounds force. Measure amount of movement. Allow blade to center. Pull the trailing edge of blade away from center with 4 to 5 pounds force, and measure amount of movement. Maximum movement allowed: 1.0 inch each side.

d. Inspect crosshead for visible damage, surface nicks and scratching. Corrosion or pitting shall be cause for rejection.

C. Repair or Replacement

Repair or replace hub and blade assembly if inspection requirements are not met. Request assistance of Direct Support maintenance personnel for repair. If assistance is not immediately available, replace the hub and blade assembly. See Appendix V for Direct/General Support maintenance procedures.

D. Installation

NOTE

Prior to installation, ensure tail rotor hub, crosshead, and pitch links are compatible for installation on helicopter.

1. Observe color coding of parts during installation.

2. Position tail rotor hub and blade assembly near end of shaft with bearing bosses of hub inboard and flat side outboard. Be sure internal bevel of hub is inboard. Align master splines and slide hub on shaft until trunnion is just started on second set of splines.

3. Place split cone set with bevel outboard, in groove between splines and shoulder on shaft with ends gaps equally spaced. Slide hub inboard

to seat trunnion on cones. Check cone set for equal spacing.

NOTE

Install split cones as matched set only.

4. Install shim on shaft against trunnion. Install static stop and hub retaining nut. Hold rotor by hub and tighten to a torque of 300 to 400 inch-pounds. A maximum of one exposed unengaged thread inside nut is permissible after shimming instructions have been accomplished. (Refer to Step 12 for shimming instructions.) Lockwire nut to static stop and install boot on shaft.

CAUTION

Ensure proper alignment of etched "V" back-to-back mating on bearing set is maintained prior to and during installation. Nuts MS17826-5 and MS17825-4 are not to be reused.

5. Install slider on shaft and into boot. Safety wire each end of boot. Place retainer plate and bearings on end of pitch change rod and secure by washer and nut. Tighten nut 60 to 85 inch-pounds torque and secure with cotter pin.

6. Determine thickness of shim required for 0.002 to 0.004 inch pinch on pitch change rod bearings as follows:

   a. With shim omitted temporarily assemble cross head and secure with two bolts, washers, and nuts.

   CAUTION

   Ensure correct P/N crosshead is installed.

   b. Tighten nuts enough to secure assembly without distortion.

   c. With a feeler gage measure gap between retainer plate and crosshead. Subtract 0.002 to 0.004

inch and peel or replace shim as necessary for this thickness.

d. Remove bolts and crosshead.

CAUTION

Recheck "V" etched on outer races of bearing set for proper back-to-back mating.

7. Fill cavity of crosshead with grease. Place shim and crosshead over bearings. Align parts and install bolts, with washers under heads, through crosshead, shim, retainer plate, and flange of slider.

NOTE

Use bolts, P/N NAS1304-21D, nuts, P/N MS17825-4, and cotter keys. P/N MS24665-151, to attach crosshead to slider. Use one steel washer under head of bolts and one steel washer under nuts. One additional thin steel washer may be used under nuts to align for cotter key.

8. Check pitch change links to ensure they are a matched pair, in serviceable condition, and properly installed in crosshead, with each bolt head toward rotation.

   a. Maximum allowable wear tolerance for rod-end bearings is 0.020 inch, either axial or radial play.

   b. Set pitch links to initial length of 5.4 inches measured between bolt hole centers. Refer to TAIL ROTOR PITCH CONTROL QUILL AND ROD.

9. Connect each pitch change link to blade pitch horn as follows:

   a. Inspect pitch change links, and determine part number of links being installed.

   b. Install links on tail rotor grips with attaching parts. Torque nuts to 60 to 100 inch-pounds, and install cotter pins.

NOTE

The pitch change link with the extended rod end bearing must contact the tail rotor grip.

10. Install pitch change links in crosshead as follows:

    a. Install bolts with washers. Install bolts with heads in direction of rotation.

    b. Torque nuts to 50 to 70 inch-pounds and install cotter pins. Use one additional thin steel washer under nuts, if necessary, for cotter pin alignment.

11. Rig tail rotor (see <u>PITCH CONTROL QUILL AND ROD</u>, paragraph D.6, 7, and 9).

12. Check for 3.0 ($\pm$0.5) inch clearance between tail boom vertical fin and nearest trailing edge of tail rotor at full right pedal position in rigged condition. If necessary, change thickness of shim installed between rotor hub trunnion and static stop for proper clearance. Use bonded laminated shims only.

CAUTION

Ensure all safety provisions are followed if adjustment of shim is required.

NOTE

Inspect hub retaining nut for proper thread engagement to shaft. A maximum of one exposed unengaged thread inside nut is permissible, after shimming is accomplished.

13. Check the tail rotor and controls for free movement, with no interference, through full flapping angle with full right and left antitorque pedal applied. If installation is not correct, interference between the pitch change links and the safety washer may occur before the rotor hub contacts the static stop.

14. Lubricate the tail rotor (see paragraph E).

15. Track tail rotor.

    a. Attach a small piece of sponge rubber 1/8 to 1/4 inch thick on the end of a 1/2-x-1/2-inch pine stick or any other flexible device. Cover sponge rubber with Prussian blue or similar type of coloring thinned with oil.

    NOTE

    Ground runup shall be performed by authorized personnel only.

    b. Start engine. Run engine at 6600 rpm, with pedals in neutral position. Rest marking device on underside of tail boom assembly. Slowly move marking device into disc of tail rotor just far enough to touch near blade approximately 1 inch from tip.

    c. When near blade is marked, stop engine and allow rotor to stop. Shorten pitch control link of marked blade and recheck track of blades.

    NOTE

    Between 5 and 10 hours of flight, after installation of tail rotor, retorque tail rotor retaining nut. Retorque can be accomplished with slider and crosshead installed with care that wrench does not contact adjacent parts.

16. Relubricate tail rotor grips after tracking. Centrifugal force may force grease away from inboard bearings. Purge grips until uncontaminated grease is expelled at inboard seal.

E. <u>Lubrication</u>

Use hand-type grease gun only.

1. Grip Bearings, 1 place. Purge lubricate tail rotor hub and blade grip bearings every 100 hours or if conditions warrant every 25 hours as follows:

    a. Disconnect pitch link at one blade grip and purge bearing with grease. Rotate grip several

times in both directions. Repeat purging procedure. Wipe off excess grease and reconnect pitch link.

b. Disconnect pitch link on opposite blade grip and purge bearing in accordance with Step a procedure. Reconnect pitch link.

2. Trunnion Bearings, 1 place each, every 100 hours.

3. Crosshead Bearing, 2 shots only, every 100 hours.

Model UH-1C

A. Removal

See UH-1D/H

B. Inspection

See UH-1D/H except:

3. Should blade movement exceed limits, inspect grip installation for proper torque on grip retaining nut. Continued excessive movement after torque check is cause for rejection.

d. Maximum allowable depth after repair of surface nicks and scratches not to exceed 0.020 inch. Maximum allowable depth after repair of corrosion or pitting not to exceed 0.015 inch. Excessive corrosion or pitting shall be cause for rejection.

C. Repair or Replacement

See UH-1D/H

D. Installation

See UH-1D/H except:

5. Torque of bearing retaining nut not specified.

7. Crosshead cavity not filled with grease, and part numbers of nuts, bolts, and cotter key not specified. Torque of nuts not specified, but rod end alignment specified at 37° - 39°.

14. Lubrication not specified in UH-1C manual.

16. Relubrication after tracking not mentioned.

E. Lubrication

See UH-1D/H except:

1. Purge-lubricate tail rotor hub and blade grip bearings after initial installation of a tail rotor hub assembly and subsequent ground run (to accomplish tracking requirements), after helicopter operation in the rain, and after every 50 hours of operation in the same manner as the UH-1D/H.

3. Hand pack when grease fitting is not installed. If installed, same as UH-1D/H.

Model AH-1G

See UH-1D/H except:

C. Repair and Replacement

AH-1G manual adds the following step:

3. Replace pitch links or crosshead parts as required if excess play is found. Maximum allowable wear for rod ends of pitch links is 0.020 inch, either axial or radial.

D. Installation

See UH-1D/H except:

3. Equal spacing of end gaps in split cone set not mentioned in AH-1G manual. AH-1G manual states "place cone set . . . with external chamfer of cone outboard."

5. Torque is specified as 50-95 inch-pounds.

7. Torque specified as 50-70 inch-pounds. Torque is not specified in UH-1D/H manual.

8. a. Maximum wear for rod end bearing is not specified.

   b. Pitch links initial length is 5.03 inches.

9. Torque nuts to 110-165 inch-pounds.

10. Torque nuts to 60-110 inch-pounds. Use of additional washer under nuts not mentioned.

12. Clearance for AH-1G is 2.65 (±0.35) inches.

14. Lubrication is not specified in AH-1G manual.

E. Lubrication

See UH-1D/H

TAIL ROTOR BLADES

Model UH-1D/H

A. Inspection

NOTE

Any repair or replacement of tail rotor blades will be performed by Direct Support maintenance level. (See Appendix V for Direct/General Support maintenance procedures)

1. Nicks and scratches

a. Nicks and scratches on the surface of the blade that are 0.008 inch, or less, deep are repairable.

b. Nicks and notches in the extreme trailing edge of the blade that are 0.050 inch, or less, deep are repairable.

2. Dents that are not deeper than 0.060 inch are acceptable. In cases where a scratch or nick is present in a dent, the depth is measured to the bottom of the scratch or nick and must be repaired.

3. Any crack, in any location, on any blade, is cause for blade replacement. Replace tail rotor hub and blade assembly.

4. Voids.

a. Between the abrasive strip and the inner doubler, along blade centerline, a void with a maximum width of 0.250 inch is acceptable.

b. At butt end, voids between skin and trailing edge, under doubler rear "fingers" are not acceptable.

c. At butt end, voids between skin and inner doubler, under front "fingers" are not acceptable.

d. At blade tip, between skins and trailing edge, in the outboard 1.00 inch voids are not acceptable.

e. In the blade body between the ends of the blade, between the skin and the core, voids not larger than 0.200 inch wide chordwise, by 0.500 inch long spanwise, are acceptable, providing spacing between centers exceeds 2.00 inches.

f. In the blade body between the ends of the blade, between the skin and the inner doubler, voids not larger than 0.500 inch wide chordwise, by 1.00 inch long are acceptable, providing spacing between centers exceeds 3.00 inches.

g. In the blade body between the ends of the blade, between the core and the inner doubler, voids not larger than 0.500 inch chordwise, by 1.500 inch spanwise, are acceptable, providing spacing between centers exceeds 3.00 inches.

NOTE

Any edge void is not acceptable. Replace tail rotor hub and blade assembly.

5. Inspect the tail rotor blades for corrosion in accordance with the following limits:

a. Skin corrosion areas inboard of station 25.0 not in excess of 0.010 inch in depth are permissible.

b. Skin corrosion areas outboard of station 25.0 not in excess of 0.015 inch in depth are permissible.

c. Corrosion areas in the abrasive strip not in excess of 0.010 inch in depth are permissible.

d. Corrosion areas in the trailing edge not deeper than 0.015 inch are permissible.

6. Inspect retention bolts for tightness and security.

7. Looseness of either retention bolt hole bushing is cause for blade replacement.

8. If overspeed, sudden stoppage, hard landing or overtorque has occurred, inspect blades.

9. Bond separation or cracks anywhere on blade is cause for blade replacement.

10. Movement of tip or root weights is cause for blade replacement.

11. Inspect all tail rotor blades for chordwise cracks in tip cap. Cracks in tip cap are repairable.

12. If one blade of pair has been damaged badly enough that metal has been torn or any bond lines have separated, both blades must be replaced.

B. <u>Repair or Replacement</u>

1. Request assistance of Direct Support maintenance personnel for repair of repairable items, as shown in paragraph A. If assistance is not immediately available, replace tail rotor hub and blade assembly. See Appendix V for Direct/General Support maintenance procedures.

2. Replace hub and blade assembly if any blade has voids in excess of limits shown in paragraph A.4.

C. <u>Cleaning</u>

Wash tail rotor blades with a solution of mild soap and water.

<u>Model UH-1C</u>

A. <u>Inspection</u>

See UH-1D/H

B. <u>Repair or Replacement</u>

See UH-1D/H

C. Cleaning

See UH-1D/H

Model AH-1G

A. Inspection

See UH-1D/H except:

1. b. Nicks or scratches not over 0.50 inch deep are repairable. (UH-1D/H/C manuals specify 0.050 inch.)

5. Inspection for corrosion not mentioned in AH-1G manual.

11. Tip cap cracks not mentioned in AH-1G manual.

B. Repair and Replacement

See UH-1D/H

C. Cleaning

See UH-1D/H

TAIL ROTOR PITCH CONTROL QUILL AND ROD

Model UH-1D/H

A. Removal

1. Remove tail rotor pitch control crosshead assembly. (Refer to TAIL ROTOR HUB AND BLADE ASSEMBLY, paragraph A.1-4.) Be sure bearings and retaining nut are removed from pitch control rod.

2. Cut lockwire and remove two bolts and cover from housing pan. Remove screw from bracket of pan.

3. Remove three nuts, washers, and guard from gear case studs.

4. Open speed rigs to allow slack in control cables. Lift chain from sprocket. If chain is to be removed, detach ends from cables by removing bolts.

5. Remove pan.

6. Pull control quill with packing and control rod out of gear case. Cover open port. Detach rod from quill by turning sprocket to disengage thread.

B. <u>Inspection</u>

1. Pitch Control Quill and Rod

a. Inspect guard, cover and pan for cracks and damage.

b. Inspect control rod for improper operation, binding, cracks, damaged threads or splines.

c. Inspect chain for faulty operation or wear.

NOTE

Joint wear of control chain may be checked by placing chain under tension and measuring length of any 32 pitches. Maxi um allowable length is 6-3/16 inches. If chain has been removed from helicopter, tension may be applied by suspending chain from one end and attaching 10-pound weight to opposite end.

d. Inspect control quill for roughness, binding, and unserviceable seals.

NOTE

Inspection of the tail rotor sprocket can be performed without removing sprocket from the helicopter. Gain access to sprocket by removing sprocket guard.

e. Lay a straight edge across top of sprocket teeth and determine if any space exists between the teeth and straight edge. During this inspection it may be noted that slight depressions are visible on the sprocket. This is caused by the chain links and should not be misconstrued as criteria for sprocket replacement.

2. Control Head

NOTE

Apply following procedure to determine amount of looseness between internal spline of tail rotor control head slider and rotor shaft spline and looseness in pitch change rod bearings and in pitch change threads.

a. Mount a dial indicator on tail rotor shaft with indicator against crosshead.

b. With left control pedal held full forward, manually test crosshead for radial play not to exceed 0.020 inch.

c. With full right pedal, repeat check for radial play not to exceed 0.035 inch.

d. With pedals held neutral, manually test for axial play (along shaft center line without radial motion) not to exceed 0.018 inch. Excessive axial play would indicate worn or loose pitch change rod bearings or worn pitch change threads.

C. Repair or Replacement

1. Replace guard, cover, or pan when cracked or damaged.

2. Replace control rod for faulty operation or visible defects such as cracks, bending, and damaged threads or splines.

3. Replace control chain when faulty operation or visible indications of excessive wear occur. When chain is replaced, replace sprocket on control quill as outlined in Step 4.

CAUTION

Do not apply any lubricant on control chain.

4. Replace sprocket if any space exists between sprocket teeth and straight edge. (See paragraph B.1.e.) To replace sprocket on control quill, proceed as follows:

NOTE

Tail rotor chain and sprocket shall be changed as a matched set.

a. Remove cotter pin and retaining nut while holding sprocket carefully in padded jaws of suitable tool or vise.

b. Remove and replace sprocket without separating other parts.

c. Reinstall retaining nut on end of control nut. Tighten 100 to 300 inch-pounds and align cotter pin holes.

d. Install cotter pin with spread ends parallel to face of sprocket and bent flat against hex face of retaining nut.

5. Replace control quill when rough or binding in operation, or for oil leaks past internal seals. Replace packing on quill housing at installation.

D. Installation

1. Insert control rod through inner end of control quill with splines meshed. Turn sprocket to engage quill control nut on threads of rod. Place O-ring on quill.

2. Uncover port on right side of 90-degree gearbox. Insert control rod carefully through rotor shaft and seat quill flanges over mounting studs.

3. Place cover pan on studs and secure temporarily with nuts and washers, and with screw through bracket on lower corner into matching plate nut of vertical fin.

4. Install pitch change control head assembly (see TAIL ROTOR HUB AND BLADE ASSEMBLY, paragraph D.5-10).

5. Install and connect control chain while rigging system.

6. Rigging

NOTE

Accomplish rigging with hydraulic boost off.

NOTE

Length specified for pitch change links is an initial setting, and may be changed after operational checks for blade track or to obtain normal pedal positioning in auto-rotative landing and right sideward flight.

a. Check that sprocket guard nuts and washers are reinstalled. Bottom out control quill by turning sprocket clockwise to end of travel.

b. Mark any convenient tooth of sprocket with grease pencil, and place a reference mark on cover pan next to marked tooth.

c. With sprocket bottomed clockwise, and left pedal held against stop, apply sufficient tension on lower cable to take out servo cylinder control valve motion. Install chain over sprocket and connect upper speed rig.

d. Adjust cable tension at 40 to 50 pounds, maintaining sprocket position.

e. Actuate control pedals through full travel and recheck sprocket tooth position to be 2-1/2 to 3-1/2 teeth off of bottom with full left pedal applied.

f. Place and hold right pedal full forward. Mark sprocket tooth opposite reference mark.

g. Pull lower chain to rotate sprocket four or five teeth counterclockwise. At this position, check that splines of pitch change slider and tail rotor shaft are securely engaged.

h. At full left pedal, without hydraulic power, check that sprocket is 2-1/2 to 3-1/2 teeth from bottom position as shown by reference mark.

NOTE

If hydraulic power is available, check full left pedal sprocket position with "boost on" to be 1/2 to 1-1/2 teeth from bottom by observing relation of sprocket and index mark.

i. Secure cable speed rigs with lockwire.

7. After rigging, install sprocket guard on mounting studs, secured by nuts and washers.

8. Check gap between flanges of quill housing and retainer. If gap is more than 0.025 but less than 0.040 inch, add one thin aluminum alloy washer between housing and retainer on each stud. If gap is more than 0.040 inch, add two thin aluminum alloy washers in the same manner. After installing, apply sealant externally around joints at inner and outer sides of quill housing.

9. Install cover secured by two bolts and lockwire.

E. Cleaning

Not covered in UH-1D/H manual.

Model UH-1C

A. Removal

See UH-1D/H except:

Change Step 2 to read:

"Open hinged cover on control housing pan by removing lockwire and bolt near lower end of cover. Disconnect cables at quick disconnect."

Delete Step 4.

B. Inspection

1. Pitch Control Quill and Rod

See UH-1D/H except:

c. Add "chain shall be replaced when the measurement between hole centerlines is 41.96 inches or greater."

Add the following steps:

f. Inspect control quill housing for oil leakage past internal seals and cork plugs.

g. Check gap between quill housing and retainer.

h. Inspect for corrosion.

i. Inspect clevis and bushing holes for excessive wear.

NOTE

If any item is replaced, the tail rotor must be tracked.

2. Control Head

See UH-1D/H

C. Repair or Replacement

See UH-1D/H

UH-1C Manual also adds the following note:

NOTE

When replacing control quill assembly it is important to prelubricate the assembly during installation. Lubricate worm threads in control quill assembly and on control tube and the splines in the quill housing and on the control tube with lubricating oil.

D. Installation

See UH-1D/H except:

7. Delete last sentence.

9. Replace with the following statement: "Close transparent cover and secure with bolt through cover into bracket in pan. Lockwire bolt to bolt-head at upper end of cover."

E. Cleaning

Clean metal parts with dry cleaning solvent. Dry with filtered compressed air. Clean transparent housing cover with materials and methods used for cabin windows.

TAIL ROTOR PITCH CONTROLS

Model AH-1G

A. Removal

See UH-1D/H except:

2. Replace with the following: "Remove fairing from right side of vertical fin."

5. Delete.

B. Inspection

See UH-1D/H except:

1. a. Delete words, "cover and pan."

b. Change to read, "Inspect chain and sprocket for faulty operation . . . "

C. Repair or Replacement of Control [illegible] nd Rod

See UH-1D/H except:

1. Delete the words, "cover, or pan".

D. Installation

See UH-1D/H except:

1. Change last sentence to read: "Place new O-ring on quill."

2. Add the following sentence: "Secure temporarily with nuts and washers."

3. Delete.

6. Rigging

NOTE

Accomplish rigging without hydraulic power, except when otherwise stated.

a. Bottom out quill by rotating sprocket clockwise to end of travel.

b. Place a reference mark with soft pencil on any tooth and on face of quill opposite the marked tooth.

c. Keeping left pedal full forward and control quill sprocket bottomed at reference mark, with bottom cable connected, pull aft on bottom part of chain with approximately 40 pounds tension and place chain on sprocket. (This is necessary to maintain sprocket position when tension is later added to top cable.)

d. Connect top cable at speed rig, and adjust tension until 40 to 50 pounds is obtained on both cables.

e. Move pedals through full travel. Sprocket should be 2-1/2 to 3-1/2 teeth off bottom (index mark) at full left pedal. Hold full left pedal, and pull forward on top chain with normal pressure (enough to actuate valve of hydraulic cylinder). Sprocket should bottom.

NOTE

With hydraulic power, sprocket should be 1/2 to 1-1/2 teeth off bottom at full left pedal.

f. When preceding steps have been accomplished, place and hold right pedal full forward. Mark tooth index at control quill sprocket. Pull forward on lower chain and push aft on top chain until sprocket rotates five more teeth past index mark. At this position, grip both tail rotor blades firmly and vibrate to check for slippage if splines of control quill and rod are disengaged at this extreme setting. Splines should still be engaged.

g. With right pedal full forward and SCAS unit centered (off), adjust stop bolt on upper arm of hydraulic cylinder walking beam to have 0.005 to 0.015 inch clearance with stop on support. With left pedal forward, adjust stop bolt on lower arm of walking beam to have 0.005 to 0.015 inch clearance with stop.

CAUTION

Clearance between stop and support must not exceed 0.015 inch as disengagement of splines on tail rotor slider could result with full right pedal and a SCAS hardover condition.

h. Place pilot's pedals even with each other. Position arm of magnetic brake square to the beam on which brake is mounted. Adjust rod-end of force gradient to connect on underside of bellcrank, and install bolt from top. Use thin aluminum alloy washer under bolt head, and standard steel washer under nut. Tighten lock-nut on rod-end.

i. Check attachment of forward end of SCAS transducer to structural panel with screw and spacer. Place controls to each extreme of travel, and check that rod-end of transducer will align to lever without bottoming out in either position. Adjust rod-end to eliminate any bottoming, and attach to upper side of lever with bolt and spacer. Use standard washer under bolt head, and thin aluminum alloy washer next to nut. Tighten lock-nut on rod-end.

NOTE

Make sure sprocket guard is centered so as not to bind on chain and sprocket throughout travel.

E. Cleaning

Clean parts with dry cleaning solvent. Dry with filtered compressed air.

TAIL ROTOR DRIVE SHAFT

Model UH-1D/H

A. Removal

1. Open hinged access doors along top of tail boom and vertical fin by releasing fasteners on left side. Also remove tail pipe fairing and vented cover over 42-degree gearbox, as necessary.

2. Remove clamp set from coupling at each end of shaft. Push shaft against flexible coupling to disengage opposite end, and lift out shaft. Remove other shafts aft of forward bearing hanger in the same manner.

B. Inspection

1. Replace shaft for any of the following conditions:

   a. Any crack

   b. Any sign of rivet failure

   c. Total indicated run-out, using dial indicator and V-blocks, in excess of 0.050 inch at any area on shaft. No straightening procedures are prescribed.

   d. Loss or partial detachment of balance strips which are bonded on tube near center.

   NOTE

   Do not mistake a single empty imprint, in bonding material next to balance strip, as an indication of a missing balance strip. This spot results from removal of a test coupon to inspect for bonding voids.

   e. Damaged or excessively worn curvic coupling teeth. There should be no radial play or backlash between mating teeth when fully meshed with V-band clamp removed.

   f. Grooves worn by V-band clamp on shaft coupling to extent that such wear prevents proper clamping.

   g. Surface damage of shaft tube exceeding limits in 2. below.

2. Classify surface damage on shaft tube as acceptable, repairable, or excessive by following limits. Define "Area A" as central portion of shaft, and "Area B" as portions within 14 inches of ends.

   a. Any damage to anodized finish requires anti-corrosion treatment in accordance with TM 55-405-3.

b. Nicks or scratches aligned within 15 degrees of spanwise axis are acceptable without repair to maximum depth of 0.002 inch in "Area A" or 0.004 inch in "Area B."

c. Other nicks or scratches must be polished out with fine abrasive cloth, provided depth of material removed does not exceed 0.008 inch in "Area A" or 0.012 inch in "Area B."

NOTE

If total reworked area on one side of shaft is 8 square inches greater than on opposite side, shaft will be out of balance and should be replaced.

d. Sharp dents are permissible to maximum depth of 0.010 inch in "Area A" and 0.015 inch in "Area B."

e. Nonsharp dents are permissible to maximum depth of 0.020 inch in "Area A" and 0.030 inch in "Area B."

NOTE

All dents should be carefully inspected for cracks, nicks, and scratches. No cracks permitted. Nicks or scratches shall be within limits. Total depth of defect shall not exceed limits for dents.

3. Inspection - Drive Shaft Clamps (Steel)

a. Inspect clamps for distortion or burrs on clamping surface.

b. Inspect length of welds. Minimum length should be 0.500 inch.

c. Inspect clamp bolts for stripped or damaged threads and self-locking nuts for serviceable condition.

d. Inspect spot welds for evidence of failure.

e. Steel clamps may be inspected by Magnetic Particle method.

4. Inspection - Drive Shaft Clamps (Aluminum)

   a. Inspect bolt holes for wear, nicks, and scratches.

   b. Inspect spot face, lug fillets, and internal "V" groove for nicks and scratches in excess of 0.008 inch and gouges or wear pattern extending into the fillet radius at bottom of internal "V."

   c. Inspect all remaining surfaces for nicks and gouges exceeding 0.010 inch.

   d. Aluminum clamps may be inspected by Fluorescent Penetrant method.

C. Repair or Replacement

Replace shafts or clamp sets which do not meet inspection requirements.

NOTE

Replace clamps as sets. Both halves of each set must be of the same part number.

NOTE

Do not intermix different part-numbered nuts. All nuts used to install any clamp must have the same part number.

D. Installation

1. Engage shaft couplings with mating fixed and flexible couplings. Install clamp sets at each end, with nuts trailing direction of rotation, and with bolted joints indexed 90 degrees to those of adjacent clamps for balance in operation.

NOTE

Clamp assemblies with different part numbers may be installed on the same drive shaft; however, clamp halves cannot be intermixed. If one-half of a clamp requires replacing, complete clamp assembly must be replaced as they are matched pairs.

NOTE

Each clamp must have nuts of the same part number installed. Do not intermix nuts.

NOTE

Determine friction torque of each nut as follows: Thread nut onto bolt until full length of each nut is on attaching bolt and then check torque.

2. Torque clamp bolts evenly to 30 to 35 inch-pounds above the nut friction torque noted above. Tap lightly around outer surface of seal clamps, and recheck torque.

3. Reinstall tail pipe fairing or gearbox cover as required. Close access doors and cowling.

E. Lubrication

Grease couplings by hand every 500 hours and at replacement of hanger bearings (see TAIL ROTOR HANGER ASSEMBLY, LUBRICATION paragraph E).

F. Cleaning

Not covered in UH-1D/H Manual.

Model UH-1C

A. Removal

See UH-1D/H. In addition the following note appears in the UH-1C Manual:

CAUTION

Clamp set shall be removed from both ends of the shaft before removing either end of the shaft from its mating curvic coupling to avoid coupling tooth or bearing damage.

B. Inspection

See UH-1D/H.

1. a. Inspect for cracks by fluorescent penetrant method. (Method not stated in UH-1D/H Manual.)

2. e. UH-1C Manual adds: "If there is distortion, cracks, evidence of shearing of rivets, static balance not within 0.1 inch-ounces, or if nicks, dents, or scratches are not within acceptable limits, the shaft shall be considered unserviceable and unrepairable."

C. Repair or Replacement

See UH-1D/H (UH-1C Manual does not contain notes that refer to replacement of clamps as sets and to the use of the same part-numbered nuts when installing clamps).

D. Installation

See UH-1D/H. UH-1C Manual adds this note:

NOTE

Maximum weight differential for matched halves is one (1) gram. Every effort should be made to retain clamp halves as matched sets. If doubt exists concerning clamp balance, the parts should be forwarded to a higher echelon for matching halves.

E. Lubrication

See UH-1D/H

F. Cleaning

Clean all shaft surfaces with dry cleaning solvent, with care, to avoid marring anodized surfaces.

Model AH-1G

A. Removal

See UH-1D/H except:

The following "Caution" note appears in the AH-1G Manual:

CAUTION

Clamp set must be removed from both ends of shaft before removing either end of shaft from its mating curvic coupling to avoid coupling tooth or bearing damage.

Add the following:

3. Remove second shaft section with oil cooler blower attached (P/N 209-040-611-1), if so equipped. Remove oil cooler blower from shaft. This assembly was used only on early AH-1G's. On later aircraft the -620-3 shaft is used in this location. See Step 2.

B. Inspection

See UH-1D/H except:

2. Add the following:

   f. Corrosion must be polished out with fine abrasive cloth, provided depth of material removal does not exceed 0.012 inch in Area B. Deeper corrosion is cause for rejection.

3. Deleted

4. d. Deleted

C. Repair or Replacement

See UH-1D/H

D. Installation

See UH-1D/H except:

1. The first note in this section (referring to matched clamp sets) does not appear in the AH-1G Manual.

E. Lubrication

See UH-1D/H except:

AH-1G Manual adds the following:

NOTE

Pack grease 0.12 inch deep over splines.

F. Cleaning

See UH-1C

TAIL ROTOR HANGER ASSEMBLY

Model UH-1D/H

A. Removal

1. Open hinged access doors along top of tail boom by releasing fasteners on left side.

2. Remove tail rotor drive shafts from each side of hanger. (Refer to TAIL ROTOR DRIVE SHAFT, Paragraph A)

3. Remove bolt, with nut and washers, at each side to detach any hanger assembly from its support fitting.

B. Inspection

Inspect for:

1. Evidence of excessive bearing wear, roughness, or binding.

NOTE

Bearing P/N 204-040-623-1 has more drag than the older type bearing. This bearing may feel slightly rough after 150 to 200 hours of operation. This is due to the special lubricant separating into minute particles. When the bearing is rotated slowly by hand with driveshaft disconnected, the rolling elements contact and spread these minute particles. This type of roughness does not constitute cause for rejection. If when rotated slowly by hand the bearing comes to a definite stop, then jumps and a corresponding increase in roughness is noted, the hanger should be replaced.

2. Cracks, elongated bolt holes, or other visible damage to hanger ring or attachment lugs.

3. Inspect hanger support fittings, in place on tail boom, for security of attachment and evidence of cracks or other damage.

CAUTION

Do not attempt to remove or change shims under fittings.

C. Repair or Replacement

Replace drive shaft hangers that do not meet the requirements of paragraph B.

D. Installation

1. Position hanger assembly, with flexible coupling forward, on support fitting.

2. Install aluminum hanger assembly by installing bolt on each side with thin steel washer next to bolt head and thin aluminum alloy washer next to hanger. Install thin aluminum alloy washer against underside of support fitting, with thin steel washer under nut. Torque nuts 50 to 70 inch-pounds.

3. Install steel or stainless steel hanger assembly by installing bolt on each side with two thin steel washers under bolt head and under nut. Torque nuts 50 to 70 inch-pounds.

4. Install drive shafts. (Refer to TAIL ROTOR DRIVE SHAFT, paragraph D.)

E. Lubrication

1. Bearing

The driveshaft hanger bearings, except bearing Part No. 204-040-623-1, may be lubricated in the field without removing the seal from the bearing or bearings from hanger by using the following equipment and procedures.

WARNING

Positively identify bearing before lubricating by the following procedure. Bearing Part No. 204-040-623-1 CANNOT be lubricated. This bearing utilizes a special lubricant. Any attempt to lubricate the 204-040-623-1 bearing will also result in seal damage which is cause for bearing rejection. Bearing must be replaced.

NOTE

These instructions do not constitute, by definition, bearing repack.

a. Obtain one hypodermic syringe.

NOTE

Prior to lubrication of bearing, drive train must be disconnected from each side of hanger assembly. Examine bearing for indications of failure (binding, overheating, etc.)

b. Using a clean, dry cloth, wipe bearing seal area as clean as possible.

c. Fill hypodermic syringe with grease, then carefully insert tapered portion of needle under lip of bearing seal. (Avoid damage to seal.) Inject a small amount of grease at each of three locations (120 degrees apart); two cc's of grease per bearing is considered sufficient. After lubrication is completed, wipe off all excess grease.

NOTE

Any damage to seal is cause for rejection of bearing.

d. Lubrication of drive shaft hanger bearing should be accomplished as dictated by environmental conditions.

2. Coupling

Coupling splines can be lubricated as described below. This procedure can be accomplished with drive shafts disconnected and hangers installed on tail boom.

a. Remove spiral lockring while holding seal plate against spring pressure.

b. Remove seal plate spring and spacer.

NOTE

Care must be taken to ensure that the retainer plug does not become unseated from inner coupling.

CAUTION

Do not use cleaning solvent inside coupling.

c. Hold couplings at full outward position. Remove old grease as thoroughly as possible.

d. Hand pack grease to 0.12 inch depth over top of internal spiine teeth. Use lubricant.

e. Keep coupling at full outward position. Ensure retainer and locking spring are properly seated. Reinstall spacer, spring, seal plate, and spiral lockring.

F. Cleaning

Not covered in UH-1D/H Manual.

Model UH-1C

A. Removal

See UH-1D/H

B. Inspection

See UH-1D/H except:

2. Delete.

Add:

4. Inspect curvic faces for distortion and evidence of excessive load.

5. Inspect mounting ears of hanger for cracks or distortion.

6. Inspect teeth of spherical couplings for cracks or galling.

7. Inspect detail parts for cracks by magnetic particle or fluorescent penetrant methods as applicable.

NOTE

If inspection reveals cracks or distortion, indicative of excessive loads, the assembly shall be considered unserviceable and unrepairable.

8. Inspect bearing seal for leakage.

C. Repair or Replacement

1. Replace hanger assemblies for excessive bearing roughness.

2. Replace hanger ring or attachment lugs if cracked, holes are elongated, or other visible damage exists.

3. Replace couplings if they fail to meet inspection requirements.

D. Installation

See UH-1D/H except:

1. Add: "Place vinyl tape between hanger assembly and support fitting."

E. Lubrication

Not covered in UH-1C Manual.

F. Cleaning

Clean exterior surfaces by wiping with cloth moistened with dry cleaning solvent.

CAUTION

Do not permit solvents or dirt to be forced into the bearing or flexible coupling by use of compressed air for drying or cleaning.

Model AH-1G

A. Removal

See UH-1D/H

B. Inspection

See UH-1D/H and add:

4. Inspect bearing seal for leakage.

NOTE

Lubrication expelled from the bearing is not in itself cause for rejection of the bearing unless an obvious defect is apparent, i.e., broken, bent, or missing seal, etc. The expelled lubricant is normally the result of overlubrication by the bearing manufacturer during bearing assembly.

New bearing assemblies which ooze grease should be observed periodically for the first 100 hours of operation. The excess grease should be wiped from the bearing. If the grease continues to ooze from the bearing in excessive amount after 100 hours, the bearing should be removed and replaced since continued lubricant loss is indicative of problems other than overlubrication of the bearing. Do not wash, clean, or spray the bearings or hanger assemblies with any type of solution during inspection. Use only clean cloths, without solvents, to wipe bearing exterior.

C. Repair and Replacement

See UH-1C

D. Installation

See UH-1C

E. Lubrication

1. Bearings are permanently lubricated at time of manufacture. No further lubrication is required.

WARNING

Attempting to lubricate bearing will cause damage to seal and render the bearing unserviceable.

F. Cleaning

See UH-1C

42-DEGREE GEARBOX

Model UH-1D/H

A. Removal

1. When replacing any gearbox, unless condition prevents operation, accomplish preservation before removal: Drain oil and reservice gearbox with corrosion preventive oil. Ground run at least ten minutes. Do not drain gearbox.

2. Remove gearbox cover and open tail rotor drive-shaft access doors.

CAUTION

As shafts are disconnected from gearbox, support unattached ends to hold shaft alignment on normal operating axis to avoid damage to hanger bearing or coupling.

3. Remove or disconnect shafts from gearbox input and output couplings.

4. Remove electrical wire from electrical chip detector.

5. Remove lockwire and four bolts, with washers, which secure gearbox on tail boom. Lift off gearbox assembly. Do not attempt to remove shims from mounting points.

6. The maximum allowable wear (elongation) for all 42° gearbox attachment holes is 0.005 inch over standard high side dimension (0.287 inch).

B. Inspection

1. Inspect gearbox case for cracks and damage .

2. Check cap assembly, vent cap, and chip detector for security. Unscrew chip detector to determine magnectic particle build up. Unscrew vent cap and determine if clean throughout.

3. Ensure that studs and nuts are tight, with no apparent leakage.

4. Inspect sight gage for damage or stain.

C. Repair or Replacement

1. Replace unserviceable oil filler cap or packing and vent breather or gasket.

CAUTION

Do not interchange filler caps of 42-degree gearbox and 90-degree gearbox. The 42-degree gearboxes are marked with a black dot on the case and a corresponding black dot on the filler cap. The 90-degree gearboxes and filler caps have white dot markings.

a. Secure chain of cap by safety pin through drilled hole in case rib at right of filler neck.

b. Lock-wire breather to drilled hole in case rib just ahead.

2. To replace other gearbox fittings, drain oil by removing drain plug from right side of gear box.

a. This plug also has a magnetic insert which can be removed, without loss of oil, to inspect for steel particles as indication of gear or bearing wear.

b. Replace packing on magnetic insert plug, and gasket on drain plug.

c. When installed, lock-wire magnetic plug to drain plug.

NOTE

Lock-wire drain plug in accordance with paragraph D.3.

3. Remove oil level sight gage retaining ring, glass, packing, and indicator disc to clean, inspect, or replace parts. To reinstall, place indicator disc in port with indexing tab in notch of inner lip. Place packing in groove around glass, install glass with flat side out, and secure with spiral retaining ring.

D. Installation

1. Check condition and security of shims at gearbox location on tail boom just ahead of vertical fin.

CAUTION

Do not attempt to remove or change shims installed on tail boom under gearbox, as any resulting misalignment could cause excessive stresses, vibration, wear and possibly eventual failure of components in tail rotor drive train.

2. Position intermediate gearbox, with oil service fittings at right side, on tail boom shims.

3. Install four bolts through corners of gearbox base into plate nuts in tail boom. Use thin aluminum alloy washers next to gear case and thin steel washers next to bolt heads. If holes in the 42° gearbox mounting flange do not exceed the dimensions given in paragraph A.6, install bolts with steel washers under head and and aluminum washer between steel washer and

flange. Torque bolts 50 to 70 inch-pounds. Lockwire left rear attachment bolt to left forward attachment bolt. Lockwire right rear attachment bolt through drain plug to right forward attachment bolt.

4. Connect electrical wire to electrical chip detector.

5. Install drive shafts (see <u>TAIL ROTOR DRIVE SHAFT</u>).

E. <u>Lubrication</u>

1. Fill gearbox to sight gage level with oil prescribed by servicing points diagram. (Refer to TM-55-1520-210-20, Chapter 1)

2. Internal splines of couplings on gearbox are packed with grease during assembly. Coupling splines can be lubricated as described below. This procedure can be accomplished with quills in place on gearbox, with drive shafts disconnected.

CAUTION

Do not intermix parts removed from forward quill with parts removed from aft quill.

a. Remove spiral lock-ring from coupling while holding seal plate against spring pressure.

b. Remove seal plate and spring.

NOTE

Care must be taken to ensure that the retainer plug does not become unseated from inner coupling.

CAUTION

Do not use cleaning solvent inside coupling.

c. Hold couplings at full outward position. Remove old grease as thoroughly as possible.

d. Hand pack grease to 0.12 inch depth over top of internal spline teeth. Use lubricant.

e. Keep coupling at full outward position, ensure retainer and locking spring are properly seated. Reinstall spring, seal plate and spiral lock-ring.

F. Cleaning

1. Clean exterior of gearbox case with dry cleaning solvent.

2. Clean vent cap as follows:

   a. Wash cap assembly in dry cleaning solvent.

   b. Flush breather passage with cleaning solvent.

   c. Dry with filtered compressed air.

3. Clean cap assembly and chip detector with dry cleaning solvent.

G. Packaging

1. Clean and dry gearbox in accordance with MIL-P-116.

2. Flush gearbox with operating oil.

3. Wrap assembly in grease-proof barrier material and secure with pressure-sensitive tape. Shape wrapper to contour of gearbox.

4. Place gearbox in contoured bottom cushion of metal container.

5. Align top contoured cushion to fit gearbox and lower in place in container.

6. Place 10 eight-unit bags (total of 80 units) of desiccant in container.

7. Install lid, with rubber gasket in place, on lower half of container.

8. Place locking ring on tip of container lid and secure with bolt and nut. Tighten nut sufficiently to ensure a moisture-vapor-proof closure.

Model UH-1C

A. Removal
See UH-1D/H and add:

7. Remove oil level sight gage retaining ring, glass, O-ring, and indicator disc as required to clean, inspect, or replace parts.

B. Inspection

See UH-1D/H and add:

5. Check O-ring packings for leakage or damage and vent breather and gasket for damage and serviceability.

C. Repair or Replacement

See UH-1D/H

D. Installation

See UH-1D/H and add:

6. Service gearbox with oil.

E. Lubrication

See UH-1D/H

F. Cleaning

See UH-1D/H and add:

4. Clean oil level sight glass.

CAUTION

Do not permit dirt or solvent to be forced into bearings or flexible couplings by use of compressed air.

5. Check condition and security of shims at gearbox location on tail boom just ahead of vertical fin.

CAUTION

Do not permit dirt or solvent to be forced into bearings or flexible couplings by use of compressed air.

5. Check condition and security of shims at gearbox location on tail boom just ahead of vertical fin.

CAUTION

DO NOT attempt to remove or change shims installed on tail boom under gearbox, as any resulting misalignment could cause excessive stresses, vibration, wear, and possibly eventual failure of components in tail rotor drive train.

G. Packaging

See UH-1D/H

Model AH-1G

A. Removal

See UH-1D/H

(Step 6 is under "Inspection", in the AH-1G Manual)

B. Inspection

See UH-1D/H paragraphs A.6 and B.; UH-1C paragraphs B and F.5. Also, add the following:

NOTE

To remove chip detector, push body of detector in and turn left to disengage bayonet pins and withdraw from drain plug.

In scheduled or special inspection for evidence of over-torque of drive system, visually inspect through gearbox filler port for scoring of output gear teeth. If scoring is found, also inspect 90° gearbox.

C. Repair or Replacement

See UH-1D/H and add:

4. Replace gearbox if

(1) Case is cracked or damaged

(2) Teeth are scored.

(3) Attachment holes are elongated over 0.292 inch.

D. Installation

See UH-1D/H and add:

Before servicing gearbox with oil determine whether system contains MIL-L-7808 oil or MIL-L-23699 oil. Splined couplings are lubricated at assembly with hand-packed lubricant to 0.12 inch deep over internal spline teeth, in same manner as tail rotor drive quill couplings.

E. Lubrication

See UH-1D/H and add:

Before servicing gearbox to sight gage level with oil, determine whether system contains MIL-L-7808 oil or MIL-23699 oil.

F. Cleaning

See UH-1D/H paragraph F and UH-1C paragraph F.4.

G. Packaging

See UH-1D/H

90-Degree Gearbox

Model UH-1D/H

A. Removal

1. Accomplish preservation before removal: Drain oil and reservice gearbox with corrosion preventive oil. Ground run at least ten minutes. Do not drain gearbox.

2. Remove tail rotor hub and blade assembly. (Refer to TAIL ROTOR HUB AND BLADE ASSEMBLY)

3. Remove pitch control mechanism, or detach cover from the fin structure and chain from control cables if replacement of gearbox or output gear quill is not required. (Refer to TAIL ROTOR PITCH CONTROL).

CAUTION

To avoid damage to gearboxes or couplings, either remove clamp set from both ends of shaft before removing either end of shaft from its mating curvic coupling, or support unattached end of shaft to hold shaft aligned on normal operating axis while gearbox is removed.

4. Open hinged access door on front of vertical fin and remove or disconnect driveshaft from input coupling of gearbox. (Refer to TAIL ROTOR DRIVE SHAFT).

5. On helicopters Serial No. 65-9565 and subsequent, remove electrical wire from electrical chip detector.

6. Detach gearbox from support casting on vertical fin by removing nuts and washers from six mounting studs around input coupling. Lift off gearbox assembly.

7. Reinstall nuts with suitable spacers on two opposite studs to secure input gear quill in case during handling or shipping.

B. Inspection

1. Inspect gearbox cases for cracks and damage.

2. Inspect quill for evidence of oil and grease leakage.

3. Check oil filler cap and O-ring packings for serviceability.

4. Inspect chip detector for excessive accumulation of metal particles.

5. Inspect gearbox breather filler cap as follows.

   a. Inspect to determine that the cap is still tightly filled with aluminum wool by slightly compressing the wool by pressing the retaining washer.

   b. If cap is properly filled with wool, the wool will return the retaining washer against the retaining ring when pressure is released.

6. Inspect gearbox input sleeve flange for protrusion of sealant in jack screw holes. Inspect mating surface of tail boom fin casting for areas of sealant remaining on casting.

7. Inspect sight gage for damage or stain.

C. Repair or Replacement

1. Replace unserviceable oil filler cap or packing. Secure cap chain by safety pin through drilled hole in filler neck boss of case.

CAUTION

Do not interchange filler caps of intermediate gearbox and tail rotor gearbox. The 90-degree gearboxes are marked with a white dot on the case and a corresponding white dot on the filler cap. The 42-degree gearboxes and filler caps have black dot markings.

2. Replace gearbox breather filler caps containing an insufficient quantity of aluminum wool.

3. To replace other gearbox fittings, drain oil by removing drain plug.

   a. Drain plug also has a magnetic insert which can be removed, without loss of oil, to inspect for steel particles as indication of gear or bearing wear.

   b. Replace packing on magnetic plug, and gasket on drain plug, as required.

   c. When reinstalled, lock-wire magnetic plug to drain plug, and drain plug to

adjacent drilled holes in boss of base.

4. Remove oil level sight gage retaining ring, glass, packing, and indicator disc to clean, inspect, or replace parts. To reinstall, place indicator disc in port with indexing tab in notch of inner lip. Place packing in groove around sight glass, install glass with flat side out, and secure with spiral retaining ring.

5. If sealant protrudes above surface of jack screw holes, trim off excess sealant. Remove any uneven areas of sealant remaining on tail boom fin casting. Any cleaned area that penetrates to the bare metal should be protected with zinc chromate primer.

D. Installation

1. Inspect 90-degree gearbox support fitting on tail boom for wear and damage limits. Repair damage, if within limits, prior to installation of gearbox. Refer to paragraph H. If damage exceeds limits, request assistance of field maintenance.

2. Remove nuts and shipping spacers from studs at input gear quill flange.

NOTE

When installing new gearbox, refer to paragraphs B.6 and C.5.

3. Position gearbox with studs engaged through support casting at top of vertical fin. Rotate box counterclockwise until studs contact sides of the holes. If holes in the 90-degree gearbox mounting flange do not exceed the dimensions given in paragraph B, install nuts with steel washers under nut and aluminum washer between steel washer and flange. Torque nuts evenly to a torque of 100 to 140 inch-pounds.

4. Install drive shaft, connected to output coupling of gearbox. (Refer to TAIL ROTOR DRIVE SHAFT.)

5. Connect electrical wire to electrical chip detector.

6. Install pitch control mechanism. (Refer to Tail Rotor Pitch Control Installation).

7. Install and rig tail rotor. (Refer to TAIL ROTOR HUB AND BLADE, paragraph D.)

8. Service gearbox with oil.

E. Lubrication

1. Fill gearbox to sight gage level with oil prescribed by servicing points diagram. (TM 55 1520-210-20, Chapter 1.)

2. Internal splines of couplings on gearbox are packed with grease during assembly. Coupling splines can be lubricated as described below. This procedure can be accomplished with quills in place on gearbox, with drive shaft disconnected.

   a. Remove spiral lock-ring from coupling while holding seal plate against spring pressure.

   b. Remove seal plate spring and spacer.

NOTE

Care must be taken to ensure that the retainer plug does not become unseated from inner coupling.

CAUTION

Do not use cleaning solvent inside coupling.

   c. Hold couplings at full outward position. Remove old grease as thoroughly as possible.

   d. Hand pack grease to 0.12 inch depth over top of internal spline teeth.

   e. Keep coupling at full outward position, ensure retainer and locking spring are properly seated. Reinstall spacer, spring, seal plate and spiral lock-ring.

F. Cleaning

1. Clean exterior of gearbox assembly, or removed parts, with dry cleaning solvent.

CAUTION

Do not permit solvent or dirt to be forced into flexible coupling by use of compressed air.

2. Clean gearbox breather filler cap as follows.

   a. Wash cap assembly in dry-cleaning solvent.

   b. Clean aluminum wool in the breather passage by flushing with dry-cleaning solvent.

   c. Dry with filtered compressed air.

G. Packaging

1. Clean and dry gearbox in accordance with MIL-P-116.

2. Flush gearbox with operating oil.

3. Wrap assembly in grease-proof barrier material and secure with pressure-sensitive tape. Shape wrapper to contour of gearbox.

4. Place gearbox in bottom contoured cushion of container.

5. Align top contoured cushion to fit gearbox and lower into container.

6. Place 12 eight-unit bags (total 96 units) of desiccant in container.

7. Install lid, with rubber gasket in place, on lower half of container.

8. Place locking ring on lip of container lid and secure with bolt and nut. Torque nut sufficiently to ensure a moisture-vapor-proof closure.

H. Repair or Replacement of Support Fitting

1. Inspect tail rotor gearbox for damage and wear in excess of limits. Request assistance of higher level of maintenance, if damage or wear exceeds limits. Repair damage or wear that is within limits as outlined in steps 2 through 5 below.

2. Blend out damage within limits with a smooth file or stone. Form a generous radius into surrounding area. Inspect the fitting after cleanup of damage to ensure that limits have not been exceeded. Touch up repaired area with zinc chromate primer.

3. Build up chafed area of repairable support fitting in area A (45 degrees on either side of the vertical fin center line) to a minimum of 0.150 inch using adhesive as a filler providing a new seat for the shaft cover.

4. Build up chafed area of repairable support fitting in area B (45 to 85 degrees on either side of the vertical fin center line) to a minimum of 0.200 inch thickness using adhesive as a filler providing a new seat for the drive shaft cover.

5. Install tape on forward upper edge of support fitting where tail rotor drive shaft cover contacts fitting.

Model UH-1C

A. Removal

See UH-1D/H except:

5. Delete the phase "On Helicopter Serial No. 65-9565 and subsequent".

B. Inspection

See UH-1D/H except:

2. Deleted

6. Deleted

7. Deleted

8. Check wear limits (elongation) of stud holes in the casting (P/N 204-030-828) do not exceed 0.010 inch over standard hole diameter (standard high side 0.319).

C. Repair or Replacement

See UH-1D/H except:

5. Deleted, add the following step:

6. Replace gearbox if cracks are found in the tail rotor gearbox case.

D. Installation

See UH-1D/H

E. Lubrication

See UH-1D/H

F. Cleaning

See UH-1D/H

G. Packaging

See UH-1D/H

H. Repair or Replacement of Support Fitting

Deleted

Model AH-1G

A. Removal

See UH-1D/H except:

2. Add: "Remove covers from both sides of the gearbox."

5. Delete the phase: "On helicopters Serial No. 65-9565 and subsequent".

B. Inspection

See UH-1C and:

4. Add:

NOTE

To remove chip detector, push body of detector in and turn left to disengage bayonet pins and withdraw from drain plug.

6. Add: "When required in scheduled or special inspections, visually inspect through gearbox filler port for scored condition of gear teeth."

C. Repair or Replacement

See UH-1D/H except:

5. Deleted, Add:

6. Replace gearbox if cracks are found in the case.

7. Replace gearbox if gears are scored.

D. Installation

See UH-1D/H. and add:

NOTE

Refer to TM 55-405-2 for re-use of self-locking nuts in critical applications.

6. "Install covers on both sides of gearbox."

8. "Before servicing gearbox with oil, determine whether system contains MIL-L-7808 oil or MIL-L-23699 oil."

E. Lubrication

See UH-1D/H and add:

Before servicing gearbox to site gage level with oil, determine whether system contains MIL-7808 or MIL-L-23699 oil. If type of oil used cannot be determined, refer to TM 55-1520-221-20, paragraph 1-7, step j.

F. Cleaning

See UH-1D/H

G. Packaging

See UH-1D/H

H. Repair or Replacement of Support Fitting

See UH-1D/H

APPENDIX II

UH-1/AH-1 TAIL ROTOR SYSTEM MEAN-TIME-TO-REMOVAL (MTR) AND MEAN-TIME-BETWEEN-REMOVAL (MTBR) ANALYSES

The results of the analyses are presented in two groups of tables. The first group presents the MTR/MTBR analyses on 42-degree and 90-degree gearboxes overhauled or scrapped at Bell Helicopter Company (BHC). The second group presents the MTR/MTBR analyses on the major tail rotor system components from data taken from the Army's Reliability and Maintainability Management Improvement Techniques (RAMMIT) Major Item Removal Frequency (MIRF) reports.

TABLE LXI. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 42-DEGREE GEARBOXES OVERHAULED OR SCRAPPED AT BHC

Aircraft Model(s): UH-1C Part No. 204-040-003-23

Reason For Removal	Records With Part Time Number	Records With Part Time MTR (Hours)	MTBR (Hours)
All Causes	12	936.2	936
Unscheduled Maintenance	5	715.0	2,247
Material Failures	2	684.5	5,617
Leakage	1	400.0	11,234
Excessive Vibration	1	969.0	11,234
External Failures	3	736.3	3,745
Crash	1	1,317.0	11,234
Hard Landing/Overstress	1	762.0	11,234
Sudden Stoppage	1	130.0	11,234
Scheduled Overhaul (TBO)	5	1,391.4	2,247
Unknown	2	349.5	5,617

TABLE LXII. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 42-DEGREE GEARBOXES OVERHAULED OR SCRAPPED AT BHC

Aircraft Model(s): UH-1D Part No. 204-040-003-23

Reason For Removal	Records With Part Time Number	Records With Part Time MTR (Hours)	MTBR (Hours)
All Causes	245	954.9	955
Unscheduled Maintenance	43	619.3	5,440
Material Failures	25	565.5	9,358
Leakage	18	585.8	12,997
Excessive Wear	4	674.0	58,485
Metal Particles in Assy	2	303.0	116,970
Internal Failure	1	292.0	233,939
External Failures	18	694.1	12,997
Sudden Stoppage	8	684.3	29,242
Hard Landing/Overstress	6	748.8	38,990
Overstress	2	984.5	116,970
Crash	1	381.0	233,939
Damaged Part- Chip, Nick, Etc.	1	176.0	233,939
Scheduled Overhaul (TBO)	153	1,149.0	1,529
Other	49	643.0	4,774
Unknown	41	622.1	5,706
No Failure	5	737.8	46,788
Manufacturing Defect	1	188.0	233,939
Scheduled Maintenance	1	1,315.0	233,939
Various	1	811.0	233,939

TABLE LXIII. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 42-DEGREE GEARBOXES OVERHAULED OR SCRAPPED AT BHC

Aircraft Model(s): UH-1C/D   Part No. 204-040-003-23

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	257	954.0	954
Unscheduled Maintenance	48	629.4	5,108
Material Failures	27	574.3	9,081
Leakage	19	576.0	12,904
Excessive Wear	4	674.0	61,293
Metal Particles in Assy	2	303.0	122,587
Internal Failure	1	292.0	245,173
Excessive Vibration	1	969.0	245,173
External Failures	21	700.1	11,675
Sudden Stoppage	9	632.7	27,241
Hard Landing/Overstress	7	750.7	35,025
Crash	2	849.0	122,587
Overstress	2	984.5	122,587
Damaged Part- Chip, Nick, Etc.	1	176.0	245,173
Scheduled Maintenance (TBO)	158	1,156.7	1,552
Other	51	631.5	4,807
Unknown	43	609.4	5,702
No Failure	5	737.8	49,035
Manufacturing Defect	1	188.0	245,173
Scheduled Maintenance	1	1,315.0	245,173
Other	1	811.0	245,173

TABLE LXIV. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 42-DEGREE GEARBOXES OVERHAULED OR SCRAPPED AT BHC

Aircraft Model(s): UH-1C Part No. 204-040-003-37

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	185	1,115.7	1,116
Unscheduled Maintenance	66	916.9	3,128
Material Failures	35	850.8	5,898
Leakage	20	870.8	10,321
Metal Particles in Assy	3	782.0	68,804
Internal Failures	2	941.0	103,206
Corrosion	2	1,090.0	103,206
Cracked/Broken	2	838.0	103,206
Excessive Wear	2	1,033.0	103,206
Excessive Vibration	2	302.5	103,206
Loose, Deteriorated, Flaking	1	485.0	206,412
Other	1	1,123.0	206,412
External Failures	31	991.5	6,659
Crash	15	1,193.7	13,761
Sudden Stoppage	8	849.0	25,802
Damaged Part- Chip, Nick, Etc.	4	1,071.8	51,603
Foreign Object Damage	1	332.0	206,412
Temperature Out of Limit	1	393.0	206,412
Overstress	1	635.0	206,412
Other	1	390.0	206,412
Scheduled Overhaul (TBO)	81	1,430.2	2,548
Other	38	790.9	5,432
Unknown	29	741.5	7,118
Scheduled Maintenance	7	878.3	29,487
No Failure	2	1,203.0	103,206

TABLE LXV. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 42-DEGREE GEARBOXES OVERHAULED OR SCRAPPED AT BHC

Aircraft Model(s): UH-1D Part No. 204-040-003-37

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	472	1,037.9	1,038
Unscheduled Maintenance	176	734.6	2,783
Material Failures	108	760.8	4,536
Leakage	72	688.9	6,804
Internal Failure	8	770.1	61,235
Excessive Wear	8	946.0	61,235
Metal Particles in Assy	7	612.9	59,983
Loose, Deteriorated, Flaking	4	943.0	122,471
Corrosion	2	1,173.0	244,942
Excessive Vibration	1	1,002.0	489,883
Cracked/Broken	1	2,487.0	489,883
Other	5	988.0	97,977
External Failures	68	692.9	7,204
Sudden Stoppage	39	734.3	12,561
Crash	11	712.2	44,535
Damaged Part - Chip, Nick, Etc.	9	419.8	54,431
Hard Landing/Overstress	3	842.0	163,294
Overstress	2	602.5	244,942
RPM Out of Limit	1	1,005.0	489,883
Improper Safety	1	1,455.0	489,883
Other	2	338.5	244,942
Scheduled Overhaul (TBO)	197	1,439.0	2,487
Other	99	779.0	4,948
Unknown	84	776.8	5,832
Scheduled Maintenance	9	870.4	54,431
No Failure	5	728.0	97,977
Manufacturing Defect	1	396.0	489,883

TABLE LXVI. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 42-DEGREE GEARBOXES OVERHAULED OR SCRAPPED AT BHC

Aircraft Model(s): UH-1H Part No. 204-040-003-37

Reason For Removal	Records With Part Time: Number	Records With Part Time: MTR (Hours)	MTBR (Hours)
All Causes	381	1,000.2	1,000
Unscheduled Maintenance	168	673.8	2,268
Material Failures	110	649.6	3,464
Leakage	80	631.8	4,763
Excessive Wear	8	669.1	47,632
Internal Failure	7	750.4	54,437
Metal Particles in Assy	5	802.4	76,212
Cracked/Broken	4	521.5	95,265
Excess Vibration	2	748.0	190,530
Corrosion	1	800.0	381,059
Other	3	636.0	127,020
External Failures	58	719.8	6,570
Sudden Stoppage	29	551.8	13,140
Crash	11	1,128.4	34,642
Overstress	5	847.2	76,212
Improper Handling/Operation	4	836.3	95,265
Foreign Object Damage	1	517.0	381,059
Temperature Out of Limit	1	450.0	381,059
Heat Damage	1	996.0	381,059
Combat Damage	1	468.0	381,059
Power Surge	1	1,235.0	381,059
Other	4	521.8	95,265
Scheduled Overhaul (TBO)	154	1,467.2	2,474
Other	59	710.4	6,459
Unknown	36	619.6	10,585
Scheduled Maintenance	19	841.3	20,056
No Failure	4	906.3	95,265

TABLE LXVII. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 42-DEGREE GEARBOXES OVERHAULED OR SCRAPPED AT BHC

Aircraft Model(s): AH-1G Part No. 204-040-003-37

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	45	680.7	681
Unscheduled Maintenance	26	556.5	1,178
Material Failures	18	524.4	1,702
Leakage	9	589.0	3,404
Excess Wear	5	520.4	6,127
Internal Failure	3	384.0	10,211
Metal Particles in Assy	1	385.0	30,633
External Failures	8	628.8	3,829
Sudden Stoppage	5	488.2	6,127
Crash	1	1,250.0	30,633
Improper Handling/Operation	1	947.0	30,633
Heat Damage	1	396.0	30,633
Scheduled Overhaul (TBO)	9	1,456.2	3,404
Other	10	305.7	3,063
Unknown	7	294.6	4,376
Scheduled Maintenance	1	699.0	30,633
Other	2	148.0	15,317

TABLE LXVIII. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 42-DEGREE GEARBOXES OVERHAULED OR SCRAPPED AT BHC

Aircraft Model(s): UH-1C/D/H, AH-1G Part No. 204-040-003-37

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	1,083	1,023.1	1,023
Unscheduled Maintenance	436	728.1	2,541
Material Failures	271	711.6	4,089
Leakage	181	678.8	6,122
Excessive Wear	23	764.7	48,173
Internal Failure	20	722.4	55,399
Metal Particles in Assy	16	689.6	69,249
Cracked, Broken	7	892.7	158,294
Corrosion	5	1,065.2	221,597
Loose, Deteriorated, Flaking	5	851.4	221,597
Excess Vibration	5	620.6	221,597
Other	9	885.7	123,110
External Failures	165	755.3	6,715
Sudden Stoppage	81	665.1	13,679
Crash	38	1,036.9	29,158
Damaged Part- Chip, Nick, Etc.	13	620.4	85,230
Overstress	8	759.5	138,499
Improper Handling/Operation	5	857.6	221,597
Hard Landing/Overstress	3	842.0	369,329
Foreign Object Damage	2	824.5	553,994
Temperature Out of Limit	2	421.5	553,994
Heat Damage	2	696.0	553,994
Combat Damage	1	468.0	1,107,987
RPM Out of Limit	1	1,005.0	1,107,987
Power Surge	1	1,235.0	1,107,987
Improper Safety	1	1,455.0	1,107,987
Other	7	450.6	158,284
Scheduled Overhaul (TBO)	441	1,447.6	2,512
Other	206	738.6	5,379
Unknown	156	712.3	7,103
Scheduled Maintenance	36	851.8	30,777
No Failure	11	879.2	100,726
Other	2	148.0	553,994
Manufacturing Defect	1	396.0	1,107,987

TABLE LXIX. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 90-DEGREE GEARBOXES OVERHAULED OR SCRAPPED AT BHC

Aircraft Model(s): UH-1C Part No. 204-040-012-7

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	17	927.8	928
Unscheduled Maintenance	7	719.1	2,253
Material Failures	4	856.8	3,943
Leakage	3	847.7	5,258
Metal Particles in Assy	1	884.0	15,773
External Failures	3	535.7	5,258
Sudden Stoppage	1	355.0	15,773
RPM Out of Limit	1	417.0	15,773
Other	1	835.0	15,773
Scheduled Overhaul (TBO)	8	1,067.4	1,972
Other	2	1,100.0	7,887
Unknown	2	1,100.0	7,887

TABLE LXX. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 90-DEGREE GEARBOXES OVERHAULED OR SCRAPPED AT BHC

Aircraft Model(s): UH-1D   Part No. 204-040-012-7

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	224	868.4	868
Unscheduled Maintenance	50	579.8	3,890
Material Failures	29	632.7	6,708
Leakage	13	646.2	14,963
Metal Particles in Assy	8	535.6	24,315
Excessive Wear	5	834.0	38,904
Cracked/Broken	1	525.0	194,518
Excess Vibration	1	776.0	194,518
Other	1	192.0	194,518
External Failures	21	506.7	9,263
Sudden Stoppage	10	417.7	19,452
Damaged Part- Chip, Nick, Etc.	3	695.3	64,839
Foreign Object Damage	2	421.0	97,259
Overstress	2	914.5	97,259
Crash	1	370.0	194,518
Hard Landing/Overstress	1	466.0	194,518
Combat Damage	1	617.0	194,518
Wrinkled, Buckled, Bent	1	253.0	194,518
Scheduled Overhaul (TBO)	119	1,092.5	1,635
Other	55	645.8	3,537
Unknown	52	649.4	3,741
No Failure	3	585.0	64,839

TABLE LXXI. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 90-DEGREE GEARBOXES OVERHAULED OR SCRAPPED AT BHC

Aircraft Model(s): UH-1C/D   Part No. 204-040-012-7

Reason For Removal	Records With Part Time: Number	Records With Part Time: MTR (Hours)	MTBR (Hours)
All Causes	241	872.6	873
Unscheduled Maintenance	57	596.9	3,689
Material Failures	33	659.8	6,373
Leakage	16	683.9	13,144
Metal Particles in Assy	9	574.3	23,366
Worn, Excess Play	5	834.0	42,058
Cracked/Broken	1	525.0	210,291
Excess Vibration	1	776.0	210,291
Other	1	192.0	210,291
External Failures	24	510.3	8,762
Sudden Stoppage	11	412.0	19,117
Damaged Part - Chip, Nick, Etc.	3	695.3	70,097
Foreign Object Damage	2	421.0	105,146
Overstress	2	914.5	105,146
Crash	1	370.0	210,291
Hard Landing/Overstress	1	466.0	210,291
Combat Damage	1	617.0	210,291
RPM Out of Limit	1	417.0	210,291
Wrinkled, Buckled, Bent	1	253.0	210,291
Other	1	835.0	210,291
Scheduled Overhaul (TBO)	127	1,090.9	1,656
Other	57	661.8	3,689
Unknown	54	664.0	3,894
No Failure	3	585.0	70,097

TABLE LXXII. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 90-DEGREE GEARBOXES OVERHAULED OR SCRAPPED AT BHC

Aircraft Model(s): UH-1C Part No. 204-040-012-13

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	180	877.7	878
Unscheduled Maintenance	63	674.1	2,508
Material Failures	43	707.4	3,674
Leakage	26	663.9	6,077
Metal Particles in Assy	8	746.6	19,749
Excessive Wear	4	803.3	39,497
Internal Failure	1	569.0	157,988
Damaged Bearing - Loose, Burnt, Etc.	1	1,113.0	157,988
Locked/Frozen	1	697.0	157,988
Other	2	671.0	78,994
External Failures	20	602.5	7,899
Sudden Stoppage	12	584.4	13,166
Crash	3	834.3	52.663
Foreign Object Damage	2	570.0	78,994
Combat Damage	1	228.0	157,988
Holes Punched	1	744.0	157,988
Other	1	421.0	157,988
Scheduled Overhaul (TBO)	88	1,085.3	1,795
Other	29	690.3	5,448
Unknown	26	703.2	6,077
No Failure	2	504.0	78,994
Scheduled Maintenance	1	727.0	157,988

TABLE LXXIII. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 90-DEGREE GEARBOXES OVERHAULED OR SCRAPPED AT BHC

Aircraft Model(s): UH-1D Part No. 204-040-012-13

Reason For Removal	Records With Part Time: Number	Records With Part Time: MTR (Hours)	MTBR (Hours)
All Causes	446	929.2	929
Unscheduled Maintenance	118	676.9	3,512
Material Failure	73	701.1	5,677
Leakage	36	681.3	11,512
Metal Particles in Assy	11	698.5	37,674
Internal Failure	7	703.9	59,202
Damaged Bearing - Burnt, Loose, Etc.	4	548.8	103,603
Cracked/Broken	3	1,067.0	138,138
Corrosion	2	995.5	207,207
Excessive Wear	2	820.0	207,207
Excess Vibration	2	508.0	207,207
Loose, Deteriorated, Flaking	1	210.0	414,913
Other	5	757.8	82,883
External Failures	45	637.6	9,209
Sudden Stoppage	24	552.2	17,267
Crash	5	816.8	82,883
Hard Landing/Overstress	4	684.5	103,603
Damaged Part - Chip, Nick, Etc.	3	703.0	138,138
Foreign Object Damage	2	291.5	207,207
Improper Handling/Operation	2	950.5	207,207
Combat Damage	1	1,003.0	414,413
Power Surge	1	602.0	414,413
Temperature Out of Limit	1	313.0	414,413
Other	2	886.5	207,207
Inspection	1	753.0	414,413
Scheduled Overhaul (TBO)	266	1,093.8	1,558

TABLE LXXIII. (Cont'd)			
Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
Other	61	702.2	6,794
Unknown	51	698.7	8,126
Scheduled Maintenance	7	686.3	59,202
No Failure	3	798.3	138,138

TABLE LXXIV. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 90-DEGREE GEARBOXES OVERHAULED OR SCRAPPED AT BHC

Aircraft Model(s): UH-1H Part No. 204-040-012-13

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	381	860.6	861
Unscheduled Maintenance	137	675.2	2,373
Material Failures	93	669.9	3,526
Leakage	46	552.0	7,128
Metal Particles in Assy	23	599.8	14,257
Internal Failure	16	1,035.6	20,494
Excessive Wear	5	794.2	65,580
Cracked/Broken	2	728.5	163,951
Other	1	1,115.0	327,902
External Failures	44	686.5	7,452
Sudden Stoppage	16	522.6	20,494
Crash	7	761.4	46,843
Overstress	5	1,059.8	65,580
Combat Damage	4	663.8	81,976
Damaged Part- Chip, Nick, Etc.	3	763.3	109,301
Hard Landing/Overstress	2	570.0	163,951
Power Surge	2	751.0	163,951
Foreign Object Damage	1	399.0	327,902
Temperature Out of Limit	1	450.0	327,902
Dent	1	1,006.0	327,902
Overtorque	1	1,003.0	327,902
Other	1	770.0	327,902
Scheduled Overhaul (TBO)	183	1,096.9	1,792
Other	61	568.2	5,375
Unknown	46	569.0	7,128
Scheduled Maintenance	10	653.7	32,709
No Failure	5	390.0	65,580

TABLE LXXV. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 90-DEGREE GEARBOXES OVERHAULED OR SCRAPPED AT BHC

Aircraft Model(s): AH-1G Part No. 204-040-012-13

Reason For Removal	Records With Part Time: Number	Records With Part Time: MTR (Hours)	MTBR (Hours)
All Causes	40	711.7	712
Unscheduled Maintenance	19	428.8	1,498
Material Failures	11	509.7	2,588
Leakage	5	483.6	5,694
Excessive Wear	2	651.0	14,235
Internal Failure	1	820.0	28,469
Metal Particles in Assy	1	49.0	28,469
Excess Oil Consumption	1	943.0	28,469
Other	1	300.0	28,469
External Failures	8	317.5	3,559
Sudden Stoppage	4	245.0	7,117
Crash	1	1,100.0	28,469
Damaged Part - Chip, Nick, Etc.	1	148.0	28,469
RPM Out of Limit	1	200.0	28,469
Overstress	1	112.0	28,469
Scheduled Overhaul (TBO)	16	1,130.1	1,779
Other	5	448.0	5,694
Unknown	4	523.0	7,117
Other	1	148.0	28,469

TABLE LXXVI. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 90-DEGREE GEARBOXES OVERHAULED OR SCRAPPED AT BHC

Aircraft Model(s): UH-1C/D/H, AH-1G Part No. 204-040-012-13

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	1,047	887.1	887
Unscheduled Maintenance	337	661.7	2,756
Material Failures	220	679.6	4,222
Leakage	113	613.9	8,219
Metal Particles in Assy	43	639.6	21,599
Internal Failure	25	915.4	37,151
Excessive Wear	13	778.9	71,444
Cracked/Broken	5	931.6	185,754
Damaged Bearing - Loose, Burnt, Etc.	5	661.6	185,754
Corrosion	2	995.5	464,386
Excess Vibration	2	508.0	464,386
Loose, Deteriorated, Flaking	1	210.0	928,772
Excess Oil Consumption	1	943.0	928,772
Locked/Frozen	1	697.0	928,772
Other	9	755.1	103,197
External Failures	117	628.1	7,938
Sudden Stoppage	56	528.7	16,585
Crash	16	813.6	58,048
Damaged Part - Chip, Nick, Etc.	7	649.6	132,682
Hard Landing/Overstress	6	646.3	154,795
Combat Damage	6	647.7	154,795
Overstress	6	901.8	154,795
Foreign Object Damage	5	424.4	185,754
Power Surge	3	701.3	309,591
Temperature Out of Limit	2	381.5	464,386
Improper Handling/Operation	2	950.5	464,386
Holes Punched	1	744.0	928,772
RPM Out of Limit	1	200.0	928,772
Dent	1	1,006.0	928,772
Overtorque	1	1,003.0	928,772
Other	4	824.5	232,193

TABLE LXXVI. (Cont'd)

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
Inspection	1	753.0	928,772
Scheduled Overhaul (TBO)	553	1,094.5	1,680
Other	156	639.4	5,954
Unknown	127	647.1	7,313
Scheduled Maintenance	18	670.4	51,598
No Failure	10	535.3	92,877
Other	1	148.0	928,772

TABLE LXXVII. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF TAIL ROTOR HUB ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1D Part No. 204-011-701-11

Reason For Removal	Records With Part Time: Number	Records With Part Time: MTR (Hours)	MTBR (Hours)
All Causes	195	389.4	389
Unscheduled Maintenance	75	439.5	1,012
Material Failures	50	481.7	1,519
Bearing Failure	22	490.9	3,451
Excessive Wear	18	503.1	4,218
Unbalanced	4	357.0	18,982
Leaking	3	371.3	25,310
Broken/Cracked	2	645.0	37,965
Other	1	399.0	75,929
External Failure Causes	25	355.0	3,037
Overspeed	10	301.2	7,593
Sudden Stop	6	297.6	12,655
Maintenance Induced	5	651.0	15,186
Burned	2	198.0	37,965
Dented	1	184.0	75,929
Foreign Object Damage	1	243.0	75,929
Retirement	10	669.3	7,593
Other Removal Reasons	110	329.8	690
No Failure Causes	49	285.1	1,550
No Defect	19	316.0	3,996
To Facilitate Other Maint	30	296.4	2,531
Other Scheduled Maintenance	26	325.6	2,920
Unknown Causes	35	395.5	2,169

TABLE LXXVIII. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF TAIL ROTOR HUB ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1D   Part No. 204-011-701-19

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	1911	150.8	151
Unscheduled Maintenance	185	197.0	1,558
Material Failures	101	237.8	2,854
Excessive Wear	58	247.3	4,970
Broken/Cracked	12	269.7	24,023
Unbalanced	8	79.6	36,035
Leaking	7	236.8	41,183
Internal Failure	6	389.3	48,047
Bearing Failure	5	260.8	57,656
Clogged	1	353.0	288,281
Other	4	38.7	72,070
External Failure Causes	84	147.8	3,431
Sudden Stop	26	125.0	11,088
Overspeed	20	159.7	14,414
Maintenance Induced	11	243.8	26,207
Chipped, Dented, Grooved, Cut	8	164.1	36,035
Accident/Crash Damage	6	36.1	48,047
Overstressed	6	141.0	48,047
Battle Damage	3	36.3	96,094
Burned	2	247.0	144,141
Foreign Object Damage	1	201.0	288,281
Induced By Other Failure	1	111.0	288,281
Retirement	84	298.8	3,432
Other Removal Reasons	1642	138.1	176
No Failure Causes	160	173.7	1,802
No Defect	97	176.5	2,972
To Facilitate Other Maint	57	178.8	5,058
Cannibalization	6	79.5	48,047
Other Scheduled Maintenance	1418	131.3	203
Unknown Causes	64	199.6	4,504

TABLE LXXIX. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF TAIL ROTOR HUB ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1D Part No. 204-011-801-5

Reason For Removal	Records With Part Time Number	Records With Part Time MTR (Hours)	MTBR (Hours)
All Causes	108	317.7	318
Unscheduled Failures	33	407.7	1,040
Material Failures	26	433.0	1,320
Excessive Wear	13	569.7	2,639
Bearing Failure	7	316.2	4,902
Leaking	2	321.0	17,156
Internal Failure	2	249.0	17,156
Clogged	1	299.0	34,311
Contamination	1	200.0	34,311
External Failure Causes	7	313.6	4,902
Overstressed	2	312.5	17,156
Sudden Stop	1	16.0	34,311
Chipped, Torn, Nicked, Cut, Etc.	1	700.0	34,311
Maintenance Induced	1	152.0	34,311
Overspeed	1	101.0	34,311
Burned	1	601.0	34,311
Retirement	1	93.0	34,311
Other Removal Reasons	74	280.6	464
No Failure Causes	49	324.2	700
No Defect	45	344.8	762
To Facilitate Other Maint.	2	70.0	17,156
Cannibalization	2	115.0	17,156
Other Scheduled Maint.	20	161.0	1,716
Unknown Causes	5	332.2	6,862

TABLE LXXX. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF TAIL ROTOR HUB ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1D Part No. 204-011-801-9

Reason For Removal	Records With Part Time Number	Records With Part Time MTR (Hours)	MTBR (Hours)
All Causes	249	238.4	238
Unscheduled Maintenance	97	284.6	612
Material Failures	74	333.8	802
Excessive Wear	51	363.8	1,164
Bearing Failure	9	269.8	6,596
Internal Failure	5	233.6	11,873
Clogged	3	242.6	19,788
Broken/Cracked	2	274.5	29,682
Leaking	1	874.0	59,365
Unbalanced	1	94.0	59,365
Other	2	152.5	29,682
External Failure Causes	23	126.5	2,581
Accident/Crash Damage	11	172.5	5,397
Sudden Stop	5	30.6	11,873
Overspeed	2	248.0	29,682
Battle Damage	1	240.0	59,365
Chipped, Torn, Nicked, Cut, Etc.	1	208.0	59,365
Maintenance Induced	1	192.0	59,365
Burned	1	36.0	59,365
Bent	1	149.0	59,365
Retirement	2	590.0	29,682
Other Removal Reasons	150	203.8	396
No Failure Causes	118	218.8	503
No Defect	105	228.7	565
To Facilitate Other Maint.	10	106.0	5,936
Cannibalization	3	248.0	19,788
Other Scheduled Maint.	12	125.0	4,947
Unknown Causes	20	163.0	2,968

TABLE LXXXI. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF TAIL ROTOR HUB ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1H Part No. 204-011-701-19

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	3078	156.9	157
Unscheduled Maintenance	261	256.4	1,850
Material Failures	134	285.8	3,603
Excessive Wear	46	241.7	10,497
Unbalanced	22	224.7	21,948
Bearing Failure	21	298.5	22,993
Broken/Cracked	16	500.0	30,178
Leaking	14	288.6	34,490
Internal Failure	11	280.7	43,896
Contamination	1	199,0	482,853
Other	3	212.7	160,951
External Failure Causes	127	225.4	3,802
Sudden Stop	54	264.7	8,942
Maintenance Induced	16	121.5	30,178
Chipped, Torn, Nicked, Cut, Etc	10	470.6	48,285
Overstressed	10	184.1	48,285
Overspeed	10	116.2	48,285
Foreign Object Damage	10	95.8	48,285
Accident/Crash Damage	9	229.5	53,650
Battle Damage	7	232.5	68,979
Bent	1	33.0	482,853
Retirement	124	334.3	3,894
Other Removal Reasons	2693	139.1	179
No Failure Causes	215	188.6	2,246
No Defect	108	169.0	4,471
To Facilitate Other Maintenance	79	209.6	6,112
Cannibalization	28	205.3	17,245
Other Scheduled Maintenance	2351	131.6	205
Manufacturing Defect	2	53.0	241,426
Unknown Causes	125	195.4	3,863

TABLE LXXXII. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF TAIL ROTOR HUB ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1H Part No. 204-011-801-5

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	426	264.0	264
Unscheduled Maintenance	132	314.6	852
Material Failures	89	370.2	1,264
Excessive Wear	41	369.7	2,743
Clogged	18	579.1	6,248
Bearing Failure	9	380.0	12,497
Internal Failure	8	189.5	14,059
Unbalanced	5	76.6	22,494
Broken/Cracked	4	289.0	28,117
Leaking	3	195.0	37,490
Broken Safety Wire	1	304.0	112,469
External Failure Causes	43	199.6	2,616
Sudden Stop	12	155.7	9,372
Accident/Crash Damage	11	240.6	10,224
Chipped, Torn, Nicked, Cut, Etc.	7	269.5	16,067
Overspeed	5	64.0	22,494
Maintenance Induced	3	248.7	37,490
Overstressed	3	145.6	37,490
Battle Damage	2	338.5	56,234
Retirement	9	318.7	12,497
Other Removal Reasons	285	238.8	395
No Failure Causes	136	299.1	827
No Defect	112	316.8	1,004
To Facilitate Other Main.	15	162.0	7,498
Cannibalization	9	306.4	12,497
Other Scheduled Maintenance	97	146.5	1,159
Manufacturing Defect	6	71.3	18,745
Unknown Causes	46	277.4	2,445

TABLE LXXXIII. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF TAIL ROTOR HUB ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1H Part No. 204-011-801-9

Reason For Removal	Records With Part Time Number	Records With Part Time MTR (Hours)	MTBR (Hours)
All Causes	2495	308.1	308
Unscheduled Maintenance	1031	330.8	746
Material Failures	732	359.2	1,050
Excessive Wear	472	291.6	1,629
Clogged	114	341.2	6,743
Bearing Failure	66	333.1	11,648
Broken/Cracked	31	306.5	24,798
Leaking	21	385.9	36,607
Internal Failure	13	330.5	59,135
Unbalanced	13	152.1	59,135
Other	2	456.5	384,376
External Failure Causes	299	261.3	2,571
Accident/Crash Damage	121	257.7	6,354
Sudden Stop	48	186.9	16,016
Chipped/Torn, Nicked, Cut, Etc.	38	242.6	20,230
Battle Damage	32	305.5	24,024
Maintenance Induced	32	302.7	24,024
Burned	8	550.1	96,094
Overstressed	7	219.1	109,822
Overspeed	7	209.4	109,822
Foreign Object Damage	3	188.0	256,251
Induced By Other Failure	2	144.0	384,376
Other	1	1043.0	768,752
Retirement	199	185.8	3.863
Other Removal Reasons	1265	312.9	608
No Failure Causes	968	303.9	794
No Defect	892	314.3	862
To Facilitate Other Maint.	25	118.6	30,750
Cannibalization	51	212.3	15,074

TABLE LXXXIII. (Cont'd)

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
Other Scheduled Maintenance	24	761.2	32,031
Manufacturing Defect	1	121.0	768,752
Unknown Causes	272	287.3	2,826

TABLE LXXXIV. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF TAIL ROTOR HUB ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): AH-1G Part No. 209-010-701-3

Reason For Removal	Records With Part Time Number	Records With Part Time MTR (Hours)	MTBR (Hours)
All Causes	1037	125.5	126
Unscheduled Maintenance	206	144.6	632
Material Failures	65	203.3	2,002
Excessive Wear	30	269.7	4,337
Unbalanced	14	97.7	9,294
Broken/Cracked	9	152.8	14,458
Internal Failure	8	162.1	16,265
Leaking	3	327.0	43,373
Overheats	1	100.0	130,118
External Failure Causes	141	117.5	923
Overspeed	77	119.9	1,690
Sudden Stop	22	104.1	5,914
Accident/Crash Damage	14	121.2	9,294
Chipped, Grooved, Nicked	12	162.2	10,843
Battle Damage	5	66.6	26,024
Foreign Object Damage	5	39.2	26,024
Maintenance Induced	4	113.2	32,530
Overstressed	2	210.0	65,059
Retirement	24	204.8	5,422
Other Removal Reasons	807	118.2	161
No Failure Causes	126	139.8	1,032
No Defect	67	151.9	1,942
To Facilitate Other Maint	50	129.2	2,602
Cannibalization	9	108.2	14,458
Other Scheduled Maintenance	646	123.5	201
Unknown Causes	35	188.8	3,718

TABLE LXXXV. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF TAIL ROTOR HUB ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): AH-1G Part No. 204-011-801-3

Reason For Removal	Records With Part Time Number	Records With Part Time MTR (Hours)	MTBR (Hours)
All Causes	875	235.0	235
Unscheduled Failures	384	271.4	535
Material Failures	278	303.1	740
Excessive Wear	183	300.3	1,124
Bearing Failure	37	268.6	5,557
Clogged	32	331.1	6,425
Leaking	11	402.0	18,691
Broken/Cracked	6	283.5	34,367
Unbalanced	5	303.0	41,120
Internal Failure	2	428.5	102,801
Corroded	2	146.0	102.801
External Failure Causes	106	188.1	1,939
Maintenance Induced	39	143.0	5,272
Accident/Crash Damage	23	238.7	8,939
Sudden Stop	19	143.6	10,821
Battle Damage	9	174.8	22,845
Chipped, Torn, Nicked, Cut, Etc.	6	419.2	34,267
Overstressed	3	201.6	68,534
Overspeed	3	321.6	68,534
Burned	3	93.3	68,534
Bent	1	204.0	205,602
Retirement	3	442.0	68,534
Other Removal Reasons	488	205.1	421
No Failure Causes	197	236.9	1,044
No Defect	153	252.6	1,344
To Facilitate Other Maint.	18	199.5	11,422
Cannibalization	24	164.7	8,567
Other Scheduled Maintenance	182	176.2	1,130
Manufacturing Defect	18	134.3	11,422
Unknown Causes	91	217.3	2,259

TABLE LXXXVI. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF TAIL ROTOR BLADE ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1D Part No. 204-011-702-15

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	1890	353.8	354
Unscheduled Maintenance	501	345.3	1,335
Material Failures	79	390.4	8,465
Excessive Wear	34	558.3	19,670
Poor Bonding	18	310.5	37,154
Unbalanced	11	334.1	60,797
Corroded	8	220.3	83,596
Internal Failure	4	115.7	167,192
Other	4	92.5	167,192
External Failure Causes	422	336.9	1,585
Dented	97	308.4	6,895
Chipped/Nicked/Cut/Cracked	81	375.8	8,256
Foreign Object Damage	71	299.7	9,419
Accident/Crash Damage	43	349.5	15,553
Sudden Stop	37	259.9	18,075
Punctured	29	369.5	23,061
Battle Damage	24	413.6	27,865
Overspeed	16	399.0	41,798
Broken	13	451.2	51,444
Overstressed	8	124.1	83,596
Burned	3	664.3	222,923
Retirement	93	871.3	7,191
Other Removal Reasons	1296	320.0	516
No Failure Causes	839	293.3	797
No Defect	720	335.1	929
To Facilitate Other Maint.	96	273.7	6,966
Cannibalization	23	329.2	29,077
Other Scheduled Maintenance	338	283.3	1,979
Unknown Causes	119	368.5	5,620

TABLE LXXXVII. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF TAIL ROTOR BLADE ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1D Part No. 204-011-702-17

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	289	191.6	192
Unscheduled Maintenance	119	137.9	465
Material Failures	3	193.0	18,462
Poor Bonding	3	193.0	18,462
External Failure Causes	116	136.5	477
Foreign Object Damage	35	118.2	1,582
Battle Damage	25	112.0	2,215
Dented	18	168.9	3,077
Chipped/Nicked/Cut/Cracked	15	191.5	3,692
Sudden Stop	7	124.1	7,912
Punctured	6	133.0	9,231
Maintenance Induced	4	174.0	13,847
Overstressed	2	268.0	27,693
Overspeed	2	36.0	27,693
Accident/Crash Damage	2	7.0	27,693
Retirement	8	933.1	6,923
Other Removal Reasons	162	194.5	342
No Failure Causes	103	203.7	538
No Defect	70	188.3	791
To Facilitate Other Maint.	24	280.1	2,308
Cannibalization	9	119.2	6,154
Other Scheduled Maint.	28	147.4	1,978
Unknown Causes	31	206.6	1,787

TABLE LXXXVIII. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF TAIL ROTOR BLADE ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1H   Part No. 204-011-702-15

Reason For Removal	Records With Part Time		MTBR (HOURS)
	Number	MTR (Hours)	
All Causes	7886	319.1	319
Unscheduled Maintenance	2888	347.1	871
Material Failures	324	383.0	7,765
Excessive Wear	157	447.1	16,026
Unbalanced	76	293.6	33,107
Poor Bonding	52	361.4	48,387
Internal Failure	29	233.4	86,763
Corroded	10	600.8	251,614
External Failures Causes	2564	342.5	981
Chipped/Nicked/Cut/Cracked	578	352.9	4,353
Battle Damage	455	362.6	5,529
Dented	369	334.5	6,818
Accident/Crash Damage	345	305.7	7,293
Broken	322	396.8	7,814
Sudden Stop	179	287.6	14,056
Foreign Object Damage	111	320.4	22,667
Punctured	72	311.2	34,946
Collapsed	49	312.4	51,349
Overstressed	36	404.9	69,892
Burned	22	408.1	114,370
Maintenance Induced	12	188.0	209,678
Overspeed	10	166.0	251,613
Induced by Other Failures	4	95.0	629,034
Retirement	213	848.8	11,812
Other Removal Reasons	4785	278.6	526
No Failure Causes	2865	320.6	878
No Defect	2145	384.6	1,173
To Facilitate Other Maint.	445	225.9	5,654
Cannibalization	275	255.2	9,150
Other Scheduled Maintenance	1196	167.0	2,104

TABLE LXXXVIII. (Cont'd)			
Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
Manufacturing Defect	2	33.0	1,258,069
Unknown Causes	722	297.0	3,484

TABLE LXXXIX. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF TAIL ROTOR BLADE ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): AH-1G Part No. 204-011-702-17

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	3068	221.0	221
Unscheduled Maintenance	1063	239.0	638
Material Failures	158	316.0	4,292
Excessive Wear	69	370.4	9,827
Unbalanced	50	254.1	13,562
Poor Bonding	18	174.1	37,671
Internal Failure	10	222.5	67,809
Corroded	5	747.8	135,617
Other	6	426.8	113,014
External Failure Causes	904	225.8	750
Chipped/Nicked/Cut/Cracked	176	264.9	3,853
Battle Damage	165	222.3	4,110
Dented	157	234.7	4,319
Accident/Crash Damage	114	185.6	5,948
Broken	96	259.8	7,063
Sudden Stop	56	160.6	12,109
Foreign Object Damage	47	177.1	14,427
Punctured	42	263.0	16,145
Overspeed	24	200.6	28,254
Maintenance Induced	14	78.0	48,435
Overstressed	8	200.2	84,761
Burned	5	400.4	135,617
Retirement	45	674.5	15,069
Other Removal Reasons	1916	200.8	346
No Failure Causes	1144	235.9	593
No Defect	880	247.6	771
To Facilitate Other Maint.	187	177.0	3,626
Cannibalization	77	245.2	8,806
Other Scheduled Maintenance	564	135.9	1,202
Unknown Causes	253	186.5	2,680

TABLE XC. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 42-DEGREE GEARBOXES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1D   Part No. 204-040-003-23

Reason For Removal	Records With Part Time Number	Records With Part Time MTR (Hours)	MTBR (Hours)
All Causes	518	717.2	717
Unscheduled Maintenance	227	526.1	1,637
Material Failures	138	576.1	2,692
Leaking	78	489.4	4,763
Excessive Wear	19	836.1	19,552
Internal Failure	16	588.4	23,218
Broken	12	750.5	30,957
Contamination	7	597.2	53,070
Overheats	2	544.5	185,744
Bearing Failure	2	407.0	185,744
Corroded	1	637.0	371,489
Loose Bolts	1	299.0	371,489
External Failure Causes	89	448.6	4,174
Sudden Stop	55	463.2	6,754
Overstressed	20	351.8	18,574
Overspeed	5	476.0	74,298
Maintenance Induced	3	823.3	123,830
Burned	2	561.5	185,744
Nicked/Chipped/Torn	2	501.0	185,744
Accident/Crash Damage	1	133.0	371,489
Foreign Object Damage	1	303.0	371,489
Scheduled Overhaul (TBO)	144	1118.5	2,580
Other Removal Reasons	147	619.1	2,527
No Failure Causes	29	472.2	12,810
No Defect	12	407.8	30,957
To Facilitate Other Maint.	17	517.6	21,852
Other Scheduled Maintenance	30	853.6	12,383
Unknown Causes	88	587.5	4,221

TABLE XCI. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 42-DEGREE GEARBOXES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1D Part No. 204-040-003-37

Reason For Removal	Records With Part Time: Number	Records With Part Time: MTR (Hours)	MTBR (Hours)
All Causes	1599	757.3	757
Unscheduled Maintenance	769	570.8	1,575
Material Failures	519	608.2	2,333
Leaking	337	608.4	3,593
Excessive Wear	71	625.5	17,056
Internal Failure	35	587.6	34,600
Contamination	35	654.9	34,600
Broken	25	586.3	48,440
Bearing Failure	7	250.8	172,999
Overheats	6	625.3	201,832
Corroded	3	853.0	403,665
External Failure Causes	250	493.2	4,844
Sudden Stop	144	512.0	8,410
Accident/Crash Damage	44	452.8	27,523
Overstressed	24	414.5	50,458
Overspeed	11	569.4	110,090
Battle Damage	10	359.1	121,099
Nicked/Chipped/Torn	8	630.0	151,374
Foreign Object Damage	5	581.6	242,199
Maintenance Induced	4	473.5	302,748
Scheduled Overhaul (TBO)	300	1369.3	4,037
Other Removal Reasons	530	681.6	2,285
No Failure Causes	168	776.6	7,208
No Defect	132	823.4	9,174
To Facilitate Other Maint.	24	601.7	50,458
Cannibalization	12	612.5	100,916
Other Scheduled Maintenance	269	583.3	4,502
Unknown Causes	93	794.3	13,021

TABLE XCII. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 42-DEGREE GEARBOXES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1H Part No. 204-040-003-37

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	2654	655.5	656
Unscheduled Maintenance	1617	543.4	1,076
Material Failures	1126	565.6	1,545
Leaking	791	561.9	2,199
Excessive Wear	150	612.7	11,599
Contamination	72	569.3	24,163
Internal Failure	55	591.8	31,631
Broken	36	551.4	48,325
Overheats	10	376.5	173,971
Bearing Failure	6	285.5	289,951
Corroded	4	353.5	434,927
Loose Bolts	1	196.0	1,739,708
External Failure Causes	492	491.6	3,536
Accident/Crash Damage	180	550.3	9,665
Sudden Stop	179	455.1	9,719
Overspeed	34	547.3	51,168
Battle Damage	30	431.2	57,990
Burned	28	466.3	62,132
Nicked/Chipped/Torn	15	401.0	115,981
Induced By Other Failure	13	481.4	133,824
Maintenance Induced	8	381.1	217,463
Foreign Object Damage	5	288.4	347,942
Scheduled Overhaul (TBO)	206	1409.9	8,445
Other Removal Reasons	830	687.4	2,096
No Failure Causes	496	754.1	3,507
No Defect	432	774.9	4,027
To Facilitate Other Maint.	35	676.5	49,706
Cannibalization	29	537.3	59,990
Other Scheduled Maintenance	135	672.7	12,887
Unknown Causes	199	531.2	8,742

TABLE XCIII. REASON FOR EMOVAL/MTR/MTBR ANALYSIS OF 42-DEGREE GEARBOXES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): AH-1G Part No. 204-040-003-37

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	976	572.1	572
Unscheduled Maintenance	604	496.7	924
Material Failures	424	536.6	1,317
Leaking	279	496.2	2,001
Excessive Wear	96	659.7	5,816
Internal Failure	23	573.6	24,275
Broken	12	547.1	46,528
Contamination	10	459.2	55,834
Overheats	3	396.0	186,112
Bearing Failure	1	217.0	558,336
External Failure Causes	180	402.6	3,102
Accident/Crash Damage	72	456.4	7,755
Sudden Stop	53	380.3	10,535
Overstressed	21	244.5	26,587
Battle Damage	9	393.4	62,037
Nicked/Chipped/Torn	9	414.0	62,037
Overspeed	6	533.8	93,056
Burned	5	440.4	111,667
Foreign Object Damage	3	354.0	186,112
Maintenance Induced	2	290.5	279,168
Scheduled Overhaul (TBO)	51	1383.7	10,948
Other Removal Reasons	321	585.0	1,739
No Failure Causes	172	599.8	3,246
No Defect	154	623.7	3,626
To Facilitate Other Maint.	10	515.2	55,834
Cannibalization	8	245.2	69,792
Other Scheduled Maintenance	43	470.4	12,985
Manufacturing Defect	1	23.0	558,336
Unknown Causes	105	611.0	5,317

TABLE XCIV. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 90-DEGREE GEARBOXES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1D Part No. 204-040-012-7

Reason For Removal	Records With Part Time		
	Number	MTR (Hours)	MTBR (Hours)
All Causes	199	729.0	729
Unscheduled Maintenance	81	543.3	1,791
Material Failures	49	582.7	2,961
Leaking	21	618.4	6,908
Contamination	11	670.5	13,189
Internal Failure	7	421.6	20,725
Excessive Wear	5	324.6	29,015
Broken	2	779.5	72,538
Bearing Failure	2	700.5	72,538
Other	1	656.0	145,076
External Failure Causes	32	483.1	4,534
Sudden Stop	12	537.4	12,090
Overstressed	9	400.2	16,120
Overspeed	3	613.7	48,359
Burned	3	26.6	48,359
Maintenance Induced	3	756.3	48,359
Accident/Crash Damage	1	525.0	145,076
Battle Damage	1	694.0	145,076
Scheduled Overhaul (TBO)	63	1088.2	2,303
Other Removal Reasons	55	591.1	2,638
No Failure Causes	20	518.7	7,254
No Defect	14	474.2	10,363
To Facilitate Other Maint.	5	725.4	29,015
Cannibalization	1	109.0	145,076
Other Scheduled Maint.	11	499.2	13,189
Unknown Causes	24	636.0	6,045

TABLE XCV. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 90-DEGREE GEARBOXES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1D   Part No. 204-040-012-13

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	1569	697.5	697
Unscheduled Maintenance	674	474.5	1,624
Material Failures	455	505.2	2,405
Leaking	209	520.0	5,236
Contamination	99	497.0	11,054
Internal Failure	57	454.1	19,199
Excessive Wear	52	582.6	21,046
Broken	30	438.4	36,479
Bearing Failure	3	441.0	364,790
Corroded	2	329.0	547,185
Other	3	235.7	364,790
External Failure Causes	219	410.6	4,997
Sudden Stop	119	392.6	9,196
Accident/Crash Damage	43	453.6	25,450
Overstressed	23	328.0	47,581
Overspeed	12	467.2	91,198
Battle Damage	8	479.7	136,796
Nicked/Chipped/Torn	6	446.0	182,395
Foreign Object Damage	4	336.2	273,593
Burned	2	399.5	547,185
Maintenance Induced	2	939.5	547,185
Scheduled Overhaul (TBO)	477	1053.7	2,294
Other Removal Reasons	418	650.6	2,618
No Failure Causes	131	532.4	8,354
No Defect	97	576.3	11,282
To Facilitate Other Maint.	29	419.4	37,737
Cannibalization	5	335.8	218,874
Other Scheduled Maintenance	203	427.1	5,391
Manufacturing Defect	1	66.0	1,094,371
Unknown Causes	83	550.6	13,185

TABLE XCVI. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 90-DEGREE GEARBOXES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1H **Part No.** 204-040-012-13

Reason For Removal	Records With Part Time		MTBR (HOURS)
	Number	MTR (Hours)	
All Causes	2812	613.6	614
Unscheduled Maintenance	1506	481.0	1,146
Material Failures	1068	498.0	1,615
Leaking	649	502.4	2,659
Excessive Wear	122	487.8	14,143
Metal on Magnetic Plug	85	520.7	20,299
Internal Failure	76	519.8	22,703
Contamination	75	483.1	23,006
Broken/Cracked	49	440.4	35,213
Bearing Failure	6	428.1	287,574
Overheats	3	552.7	575,148
Corroded	2	237.0	862,722
Loose Bolts	1	45.0	1,725,444
External Failures Causes	438	439.5	3,939
Sudden Stop	159	435.1	10,851
Accident/Crash Damage	134	416.5	12,876
Battle Damage	39	409.1	44,242
Nicked/Chipped/Torn	27	502.0	63,905
Overspeed	22	489.0	78,429
Overstressed	20	447.2	86,272
Maintenance Induced	14	412.2	123,246
Foreign Object Damage	8	444.5	215,680
Induced By Other Failure	7	738.8	246,492
Burned	6	486.3	287,574
Punctured	2	412.0	862,922
Scheduled Overhaul (TBO)	395	1073.3	4,368
Other Removal Reasons	911	633.5	1,894
No Failure Causes	574	697.2	3,006
No Defect	489	738.7	3,529
To Facilitate Other Maint.	46	510.3	37,510
Cannibalization	39	396.6	44,242

TABLE XCVI. (Cont'd)			
Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
Other Scheduled Maint.	98	621.1	17,607
Unknown Causes	239	485.6	7,219

TABLE XCVII. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF 90-DEGREE GEARBOXES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): AH-1G Part No. 204-040-012-13

Reason For Removal	Records With Part Time: Number	Records With Part Time: MTR (Hours)	MTBR (Hours)
All Causes	862	550.2	550
Unscheduled Maintenance	483	432.4	982
Material Failures	321	469.8	1,478
Leaking	164	455.9	2,892
Excessive Wear	61	495.1	7,775
Contamination	38	588.6	12,482
Internal Failure	37	386.8	12,819
Broken	16	431.6	29,644
Corroded	2	404.5	237,151
Bearing Failure	1	473.0	474,303
Other	2	483.5	237,151
External Failure Causes	162	358.5	2,928
Sudden Stop	51	372.9	9,300
Accident/Crash Damage	46	373.7	10,311
Overstressed	22	346.7	21,559
Maintenance Induced	16	313.7	29,644
Overspeed	8	350.8	59,288
Nicked/Chipped/Torn	8	385.1	59,288
Battle Damage	7	374.1	67,758
Burned	2	107.5	237,151
Foreign Object Damage	2	246.5	237,151
Scheduled Overhaul (TBO)	85	1058.7	5,580
Other Removal Reasons	294	596.7	1,613
No Failure Causes	142	622.0	3,340
No Defect	119	649.7	3,986
To Facilitate Other Maint.	13	498.6	36,485
Cannibalization	10	452.4	47,430
Other Scheduled Maintenance	68	489.7	6,975
Unknown Causes	84	640.7	5,646

TABLE XCVIII. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF T/R DRIVE SHAFT HANGER ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1D Part No. 204-040-600-7

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	5202	372.5	373
Unscheduled Maintenance	3007	142.9	645
Material Failures	2380	580.2	814
Excessive Wear	962	602.0	2,015
Bearing Failure	680	637.2	2,850
Leaking	524	465.3	3,699
Broken	81	555.6	23,927
Internal Failure	79	639.0	24,533
Overheats	46	555.5	42,132
Contamination	4	533.5	484,521
Corroded	1	76.0	1,938,084
Other	3	500.0	646,028
External Failure Causes	627	465.1	3,091
Sudden Stop	377	481.0	5,141
Overstressed	86	225.4	22,536
Cut/Nicked/Cracked/Torn	60	502.9	32,301
Accident/Crash Damage	34	621.1	57,002
Overspeed	24	594.1	80,754
Burned/Heat Damage	22	603.3	88,095
Maintenance Induced	11	537.3	176,189
Foreign Object Damage	9	393.5	215,343
Battle Damage	4	656.5	484,521
Overhaul	601	1010.8	3,225
Other Removal Reasons	1594	565.1	1,216
No Failure Causes	549	519.0	3,530
No Defect	251	557.2	7,721
To Facilitate Other Maint.	288	477.2	6,729
Cannibalization	10	767.1	193,808
Other Scheduled Maintenance	680	588.9	2,850
Unknown Causes	365	590.2	5,310

TABLE XCIX. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF T/R DRIVE SHAFT HANGER ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1D Part No. 204-040-600-9

Reason For Removal	Records With Part Time: Number	Records With Part Time: MTR (Hours)	MTBR (Hours)
All Causes	3864	430.2	430
Unscheduled Maintenance	2501	414.5	665
Material Failures	2145	418.3	775
Excessive Wear	1104	422.6	1,506
Bearing Failure	641	443.3	2,593
Leaking	285	366.3	5,833
Internal Failure	68	333.1	24,447
Contamination	20	525.1	83,119
Broken	15	374.9	110,826
Overheats	6	107.1	277,064
Corroded	5	438.6	332,477
Other	1	33.0	1,662,384
External Failure Causes	356	389.9	4,670
Sudden Stop	139	350.2	11,960
Accident/Crash Damage	109	450.9	15,251
Overstressed	38	281.5	43,747
Overspeed	23	527.3	72,278
Cut/Nicked/Cracked/Torn	19	401.3	87,494
Maintenance Induced	18	330.7	93,355
Burned/Heat Damage	5	542.8	332,477
Battle Damage	2	706.0	831,192
Foreign Object Damage	2	478.5	831,192
Induced By Other Failure	1	500.0	1,662,384
Overhaul	28	570.9	59,371
Other Removal Reasons	1335	456.8	1,245
No Failure Causes	387	467.9	4,296
No Defect	293	527.6	5,674
To Facilitate Other Maint.	75	294.1	22,165
Cannibalization	19	234.4	87,494
Other Scheduled Maintenance	774	484.0	2,148
Unknown Causes	174	311.2	9,554

TABLE C. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF T/R DRIVE SHAFT HANGER ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1H Part No. 204-040-600-7

Reason For Removal	Records With Part Time		MTBR (Hours)
	Number	MTR (Hours)	
All Causes	798	560.4	560
Unscheduled Maintenance	503	625.0	889
Material Failures	381	639.8	1,174
Excessive Wear	196	734.5	2,282
Bearing Failure	101	638.0	4,428
Leaking	73	423.7	6,126
Corroded	4	388.2	111,806
Internal Failure	3	246.3	149,074
Overheats	3	293.0	149,074
Contamination	1	1246.0	447,222
External Failure Causes	122	578.8	3,666
Sudden Stop	49	705.5	9,127
Cut/Nicked/Cracked/Torn	24	556.9	18,634
Accident/Crash Damage	19	367.3	23,538
Overstressed	14	369.6	31,944
Battle Damage	6	450.1	74,537
Overspeed	6	710.8	74,537
Maintenance Induced	3	1087.0	149,074
Foreign Object Damage	1	300.0	447,222
Overhaul	5	404.8	89,444
Other Removal Reasons	290	451.1	1,542
No Failure Causes	109	545.5	4,102
No Defect	62	516.0	7,213
To Facilitate Other Maint	38	597.6	11,769
Cannibalization	9	530.3	49,691
Other Scheduled Maintenance	159	408.2	2,813
Unknown Causes	22	294.1	20,328

TABLE CI. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF T/R DRIVE SHAFT HANGER ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): UH-1H Part No. 204-040-600-9

Reason For Removal	Records With Part Time		
	Number	MTR (Hours)	MTBR (Hours)
All Causes	10648	515.1	515
Unscheduled Maintenance	7738	505.8	709
Material Failures	6361	515.1	862
Excessive Wear	4022	545.3	1,364
Leaking	1062	398.5	5,165
Bearing Failure	981	508.0	5,591
Contamination	113	623.4	48,540
Internal Failure	71	534.0	77,254
Broken	70	490.0	78,358
Corroded	23	467.7	238,480
Overheats	18	486.5	304,724
Loose Bolts	1	54.0	5,485,034
External Failure Causes	1377	462.8	3,983
Accident/Crash Damage	621	486.4	8,833
Sudden Stop	365	464.1	15,027
Maintenance Induced	112	414.7	48,974
Overstressed	73	491.5	75,137
Battle Damage	53	364.9	103,491
Cut/Nicked/Cracked/Torn	51	385.6	107,550
Burned/Heat Damage	46	482.6	119,240
Overspeed	42	349.2	130,596
Foreign Object Damage	8	714.1	685,629
Induced By Other Failures	3	328.6	1,828,345
Other	3	300.0	1,828,345
Overhaul	21	585.1	261,192
Other Removal Reasons	2889	539.5	1,899
No Failure Causes	1509	536.9	3,635
No Defect	1348	553.2	4,069
To Facilitate Other Maint.	84	413.2	65,298
Cannibalization	77	386.7	71,234

TABLE CI. (Cont'd)

Reason For Removal	Records With Part Time		MTBR
	Number	MTR (Hours)	(Hours)
Other Scheduled Maintenance	675	612.0	8,126
Unknown Causes	705	475.7	7,780

TABLE CII. REASON FOR REMOVAL/MTR/MTBR ANALYSIS OF T/R DRIVE SHAFT HANGER ASSEMBLIES FROM RAMMIT MIRF REPORT DATA

Aircraft Model(s): AH-1G Part No. 204-040-600-9

Reason For Removal	Records With Part Time		
	Number	MTR (Hours)	MTBR (Hours)
All Causes	2515	435.2	435
Unscheduled Maintenance	1679	430.4	652
Material Failures	1378	441.1	794
Excessive Wear	832	409.8	1,316
Bearing Failure	257	474.4	4,259
Leaking	234	341.6	4,678
Contamination	24	475.1	45,606
Internal Failure	15	343.6	72,970
Overheats	7	680.7	156,365
Broken	6	291.1	182,426
Corroded	2	261.5	547,278
Unbalanced	1	471.0	1,094,556
External Failure Causes	301	381.2	3,636
Accident/Crash Damage	105	433.8	10,424
Sudden Stop	100	350.8	10,946
Maintenance Induced	41	554.3	26,696
Overstressed	16	134.6	68,410
Battle Damage	15	199.8	72,970
Cut/Nicked/Cracked/Torn	10	307.4	109,456
Burned/Heat Damage	9	199.2	121,617
Overspeed	4	286.0	273,639
Foreign Object Damage	1	232.0	1,094,556
Overhaul	4	375.7	273,639
Other Removal Reasons	832	445.2	1,316
No Failure Causes	365	375.1	2,999
No Defect	339	376.2	3,229
To Facilitate Other Maint.	17	199.7	64,386
Cannibalization	9	665.8	121,617
Other Scheduled Maintenance	244	545.0	4,486
Unknown Causes	223	465.6	4,908

APPENDIX III

UH-1/AH-1 TAIL ROTOR SYSTEM MISHAP/ACCIDENT DATA MATERIAL FAILURE ANALYSIS

The results of the analysis are presented in two groups of tables. The first group (Tables CIII through CVI) presents the failed item and/or mode by mishap classification. The second group (Tables CVII through CX) presents the failed item and/or mode by the aircraft model for which it was reported.

TABLE CIII. 42-DEGREE GEARBOX FAILURES RESULTING IN MISHAPS TO MODELS UH-1C/D/H AND AH-1G, GROUPED BY MISHAP CLASSIFICATION (Data Period, 1-1-67 thru 3-31-71)

Failed Item/Mode	Number of Mishaps: Mishap Class 1	2	3	4	5	6	All	λ_m*
G/B Failure	-	1	-	2	2	5	10	0.85
G/B Failure/Metal Chips on Plug	-	-	-	-	-	3	3	0.25
G/B Failed/Tore Loose from A/C	-	1	-	-	-	-	1	0.09
Spline	-	-	-	-	1	1	2	0.17
Output Seal	1	-	-	-	-	1	2	0.17
Plug	-	-	-	-	-	1	1	0.09
Wire on Plug/Broken	-	-	-	-	-	1	1	0.09
Coupling	-	-	-	-	-	1	1	0.09
Input Coupling	-	1	-	-	1	-	2	0.17
Gears	-	-	-	-	-	1	1	0.09
Input Bevel Gear	-	-	-	1	-	-	1	0.09
TOTAL MATERIAL FAILURES	1	3	-	3	4	14	25	2.14
λ_m*	0.09	0.25	-	0.25	0.34	1.21	2.14	
TIME BASE (flight hours)	11,699,000							

*λ_m = Mishap rate per million flight hours

TABLE CIV. 90-DEGREE GEARBOX FAILURE RESULTING IN MISHAPS TO MODELS UH-1C/D/H AND AH-1G, GROUPED BY MISHAP CLASSIFICATION (Data Period, 1-1-67 thru 3-31-71)

Failed Item/Mode	Number of Mishaps							λ_m*
	Mishap Class						All	
	1	2	3	4	5	6		
G/B Failure	4	4	-	4	6	37	55	4.70
G/B & T/R Separated	4	8	-	2	-	-	14	1.20
G/B Failed/90° G/B & T/R Separated	2	4	-	-	2	-	8	0.68
Hi-Frequency Vibration, Suspected G/B Failure	-	-	-	1	-	-	1	0.09
Input Coupling	1	-	-	-	1	-	2	0.17
Quill Assy.	-	-	-	1	-	1	2	0.17
Mount	-	1	-	1	-	-	2	0.17
Metal Particles on Plug	-	-	-	-	-	8	8	0.68
Wire on Plug Loose	-	-	-	-	-	1	1	0.09
Gears	-	-	-	-	2	2	4	0.34
G/B Seal	-	-	-	-	-	4	4	0.34
TOTAL MATERIAL FAILURES	11	17	-	9	11	53	101	8.63
λ_m*	0.94	1.45	-	0.77	0.94	4.52	8.63	
TIME BASE (flight hours)	11,699,000							

* λ_m = Mishap rate per million flight hours

TABLE CV. TAIL ROTOR DRIVE SYSTEM FAILURES RESULTING IN MISHAPS, GROUPED BY MISHAP CLASSIFICATION (Data Period 1-1-67 thru 3-31-71)

Failed Item/Mode	Number of Mishaps: Mishap Class 1	2	3	4	5	6	All	λ_m*
No. 1 Hanger Bearing	5	-	-	-	2	15	22	1.88
No. 2 Hanger Bearing	3	-	1	-	-	5	9	0.77
No. 3 Hanger Bearing	-	-	-	-	2	2	4	0.34
No. 4 Hanger Bearing	-	-	-	-	-	3	3	0.26
---- Hanger Bearing	2	2	-	-	4	17	25	2.14
Hanger Bearing Bolt/Backed Off	1	-	-	-	-	-	1	0.09
T/R Drive Quill	-	-	-	-	-	1	1	0.09
T/R Quill Couplings	2	2	-	-	4	1	9	0.77
T/R Assembly	-	2	-	1	-	-	3	0.26
T/R Quill, Control Tube/Nicked	-	-	-	-	-	1	1	0.09
T/R D/S Assembly	2	2	-	5	2	1	12	1.03
T/R D/S Clamp	-	-	-	-	1	-	1	0.09
T/R D/S Coupling	2	2	-	6	-	1	11	0.94

TABLE CV. (Cont'd)

Failed Item/Mode	Number of Mishaps Mishap Class 1	2	3	4	5	6	All	λ_m*
T/R D/S Coupling Seal	-	1	-	-	-	-	1	0.09
T/R Drive System Failure	-	2	-	-	-	-	2	0.17
TOTAL MATERIAL FAILURES	17	13	1	12	15	47	1.05	8.98
λ_m*	1.45	1.11	0.09	1.11	1.37	3.93	9.06	
Time Base (flight hours)	11,699,000							

* λ_m = Mishap rate per million flight hours

TABLE CVI. TAIL ROTOR AND PITCH CHANGE CONTROL FAILURES RESULTING IN MISHAPS TO MODELS UH-1C/D/H AND AH-1G, GROUPED BY MISHAP CLASSIFICATION
(Data Period, 1-1-67 thru 3-31-71)

Failed Item/Mode	Number of Mishaps							λ_m*
	1	2	3	4	5	6	All	
T/R/Suspected Failure	16	15	-	5	6	5	47	4.02
T/R Failure/T/R and/or 90° G/B Separated	4	5	1	3	-	-	13	1.11
T/R and/or 90° G/B Separated/Cause Unknown	1	6	-	1	-	-	8	0.68
T/R Control/Suspected Failure	-	1	-	-	-	-	1	0.09
T/R Bearing	-	1	-	4	3	1	9	0.77
Pin/Sheared, Loss of Torque on Retainer Nut	-	-	-	1	-	-	1	0.09
Pin on Yoke Bearing Retainer Nut/ Sheared, Nut Lost Torque	1	-	-	-	-	-	1	0.09
Cotter Key/Broke	-	-	-	-	1	-	1	0.09
Self-Locking Nut	1	-	-	-	-	1	2	0.17
T/R Hub	3	3	1	2	-	5	14	1.20
T/R Grip	-	2	1	1	1	-	5	0.43
T/R Yoke	4	5	-	1	-	1	11	0.94
Keeper on Grip Retainer Nut	-	-	-	-	1	-	1	0.09
T/R Hub Thrust Bearing	-	-	-	-	1	1	2	0.17
T/R Blade/Skin Unbonded	-	-	-	-	1	-	1	0.09
T/R Blade	-	-	-	-	-	2	2	0.17
Pitch Change Mechanism	-	-	-	-	-	1	1	0.09

TABLE CVI. (Cont'd)

Failed Item/Mode	Number of Mishaps: Mishap Class 1	2	3	4	5	6	All	λ_m*
Crosshead Bearing	-	-	-	-	2	1	3	0.26
Crosshead Shear Pin	-	-	-	-	-	1	1	0.09
Crosshead Bearing/Fell Out	-	-	-	-	-	1	1	0.09
Crosshead Retaining Bolt	1	-	-	-	-	-	1	0.09
P/C/L Bearing	-	-	-	-	-	1	1	0.09
P/C/L/Worn, Caused Binding	1	-	-	-	-	2	3	0.26
P/C/L Nut Broke	-	-	-	1	-	-	1	0.09
Control Tube, Control Tube Nut or Cotter Key/Sheared, Failed	1	1	-	2	7	3	14	1.19
Slider/Lacked Lube, Failed	-	-	-	-	-	2	2	0.17
Self-Locking Nuts on P/C Shaft	-	-	-	-	1	-	1	0.09
T/R Control Quill Assembly	-	1	-	2	3	2	8	0.68
T/R Control Quill Housing	-	-	-	-	-	1	1	0.09
T/R Control Quill Sprocket Guard/ Worn	-	-	-	-	-	1	1	0.09
T/R Control Quill Sprocket Wheel/ Worn	-	-	-	-	-	1	1	0.09
T/R Control Quill Sprocket/Loose	-	-	-	1	1	-	2	0.17
T/R Control Quill Sprocket	-	-	-	-	-	1	1	0.09
Control Chain/Broke	-	-	-	-	1	-	1	0.09
Control Chain/Stretched	-	-	-	-	-	1	1	0.09

TABLE CVI. (Cont'd)

Failed Item/Mode	Number of Mishaps							λ_m*
	Mishap Class						All	
	1	2	3	4	5	6		
Control Chain/Twisted	-	-	-	-	-	1	1	0.09
Control Chain/Failed	-	-	-	2	1	7	10	0.85
TOTAL MATERIAL FAILURES	33	40	3	26	30	43	175	14.96
λ_m*	2.82	3.42	0.26	2.22	2.56	3.68	14.96	
TIME BASE (flight hours)	11,699,000							

* λ_m = Mishap rate per million flight hours

TABLE CVII. 42-DEGREE GEARBOX FAILURES RESULTING IN MISHAPS, GROUPED BY MODEL (Data Period 1-1-67 thru 3-31-71)

Failed Item/Mode	Aircraft Model									
	UH-1C		UH-1D		UH-1H		AH-1G		All	
	No.	λ_m*	No.	λ_m*	No.	λ_m*	No.	λ_m*	No.	λ_m*
G/B Failure	2	1.60	4	0.99	3	0.55	1	1.05	10	0.85
G/B Failure/Metal Chips on Plug	-	-	2	0.49	1	0.18	-	-	3	0.25
G/B/Tore Loose From A/C	-	-	-	-	1	0.18	-	-	1	0.09
G/B Spline	-	-	2	0.49	-	-	-	-	2	0.17
Output Seal	-	-	2	0.49	-	-	-	-	2	0.17
Wire on Plug/Broken	-	-	1	0.25	-	-	-	-	1	0.09
Plug	-	-	1	0.25	-	-	-	-	1	0.09
Coupling	-	-	1	0.25	-	-	-	-	1	0.09
Input Coupling	-	-	-	-	2	0.37	-	-	2	0.17
Gears	-	-	1	0.25	-	-	-	-	1	0.09
Input Bevel Gear	-	-	-	-	-	-	1	1.05	1	0.09
TOTAL MATERIAL FAILURES	2	1.60	14	3.49	7	1.28	2	2.10	25	2.14
TIME BASE (flight hours)	1,250,000		4,050,000		5,450,000		949,000		11,699,000	

* λ_m = Mishap Rate per million flight hours

TABLE CVIII. 90-DEGREE GEARBOX FAILURE RESULTING IN MISHAPS, GROUPED BY MODEL
(Data Period 1-1-67 thru 3-31-71)

Failed Item/Mode	Aircraft Model									
	UH-1C		UH-1D		UH-1H		AH-1G		All	
	No.	λ_m*	No.	λ_m*	No.	λ_m*	No.	λ_m*	No.	λ_m*
G/B Failure	3	2.40	25	6.17	15	2.75	12	12.64	55	4.70
G/B and T/R Separated/Cause Unknown	2	1.60	1	0.25	9	1.65	2	1.11	14	1.20
G/B Failed/90° G/B and T/R Separated	1	0.80	2	0.49	1	0.18	4	4.21	8	0.68
Vibration/Suspected G/B Failure	-	-	-	-	1	0.18	-	-	1	0.09
Input Coupling	-	-	1	0.25	1	0.18	-	-	2	0.17
Quill Assy.	-	-	1	0.25	-	-	1	1.05	2	0.17
Mount	-	-	1	0.25	-	-	1	1.05	2	0.17
Metal Particles on Plug	-	-	4	0.99	-	-	4	4.21	8	0.68
Wire on Plug Loose	-	-	1	0.25	-	-	-	-	1	0.09
Gears	-	-	-	-	4	0.73	-	-	4	0.34
Seal	-	-	-	-	4	0.73	-	-	4	0.34
TOTAL MATERIAL FAILURES	6	4.80	36	8.89	35	6.42	24	25.29	101	8.63
TIME BASE (flight hours)	1,250,000		4,050,000		5,450,000		949,000		11,699,000	

* λ_m = Mishap rate per million flight hours

TABLE CVIX. TAIL ROTOR DRIVE SYSTEM FAILURES RESULTING IN MISHAPS, GROUPED BY MODEL

(Data Period 1-1-67 thru 3-31-71)

FAILED ITEM/MODE	AIRCRAFT MODEL									
	UH-1C		UH-1D		UH-1H		AH-1G		ALL	
	No.	λ_m*	No.	λ_m*	No.	λ_m*	No.	λ_m*	No.	λ_m*
No. 1 Hanger Bearing	1	0.80	15	3.70	5	0.92	1	1.05	22	1.88
No. 2 Hanger Bearing	-	-	5	1.23	4	0.73	-	-	9	0.77
No. 3 Hanger Bearing	-	-	2	0.49	1	0.18	1	1.05	4	0.34
No. 4 Hanger Bearing	-	-	2	0.49	1	0.18	-	-	3	0.26
---- Hanger Bearing	-	-	15	3.70	9	1.65	1	1.05	25	2.14
Hanger Bearing Bolt/Backed Off	-	-	-	-	1	0.18	-	-	1	0.09
T/R Quill Drive Quill	-	-	1	0.25	-	-	-	-	1	0.09
T/R Quill Couplings	5	4.00	2	0.49	2	0.37	-	-	9	0.77
T/R Quill Assy	-	-	1	0.25	2	0.37	-	-	3	0.26
T/R Quill, Control Tube/Nicked	1	0.80	-	-	-	-	-	-	1	0.09
T/R D/S Assy	-	-	2	0.49	9	1.65	1	1.05	12	1.03
T/R D/S Clamp	1	0.80	-	-	-	-	-	-	1	0.09
T/R D/S Coupling	-	-	7	1.73	4	0.73	-	-	11	0.94

TABLE CVIX. (Cont'd)

FAILED ITEM/MODE	AIRCRAFT MODEL									
	UH-1C		UH-1D		UH-1H		AH-1G		ALL	
	No.	λ_m*	No.	λ_m*	No.	λ_m*	No.	λ_m*	No.	λ_m*
T/R D/S Coupling Seal Failed	-	-	-	-	1	0.18	-	-	1	0.09
T/R Drive System Failure, Cause Unknown	-	-	-	-	2	0.37	-	-	2	0.17
TOTAL MATERIAL FAILURES	8	6.40	52	12.84	41	7.52	4	4.21	1.05	8.98
TIME BASE (flight hours)	1,250,000		4,050,000		5,450,000		949,000		11,699,000	

* λ_m = Mishap rate per million flight hours

TABLE CX. TAIL ROTOR & PITCH CHANGE CONTROL FAILURES RESULTING IN MISHAPS, GROUPED BY MODEL

(Date Period, 1-1-67 thru 3-31-71)

FAILED ITEM/MODE	AIRCRAFT MODEL									
	UH-1C		UH-1D		UH-1H		AH-1G		ALL	
	No.	λ_m *	No.	λ_m *	No.	λ_m *	No.	λ_m *	No.	λ_m *
T/R/Suspected Failure	9	7.2	8	1.98	20	3.67	10	10.54	47	4.02
T/R and/or 90° G/B Separated/ Cause Unknown	-	-	3	0.74	3	0.55	2	2.11	8	0.68
T/R Failure/T/R and/or 90° G/B Separated	5	4.00	1	0.25	3	0.55	4	4.21	13	1.11
T/R Control/Suspected Failure	-	-	-	-	-	-	1	1.05	1	0.09
T/R Bearing	1	0.80	1	0.25	5	0.92	2	2.11	9	0.77
Pin/Sheared, Loss of Torque Retainer Nut	-	-	1	0.25	-	-	-	-	1	0.09
Pin on Yoke Bearing Retainer Nut/Sheared, Nut Lost Torque	-	-	1	0.25	-	-	-	-	1	0.09
Cotter Key/Broke	-	-	-	-	1	0.18	-	-	1	0.09
Self-Locking Nut	-	-	2	0.49	-	-	-	-	2	0.17
T/R Hub	1	0.80	5	1.23	6	1.10	2	2.11	14	1.20
T/R Grip	-	-	1	0.25	1	0.18	3	3.16	5	0.43
T/R Yoke	-	-	6	1.48	2	0.37	3	3.16	11	0.94
Keeper on Grip Retainer Nut	-	-	-	-	-	-	1	1.05	1	0.09
T/R Hub Thrust Bearing	-	-	-	-	1	0.18	1	1.05	2	0.17
T/R Blade/Skin Unbonded	1	0.80	-	-	-	-	-	-	1	0.09

TABLE CX. (Cont'd)

FAILED ITEM/MODES	AIRCRAFT MODEL									
	UH-1C		UH-1D		UH-1H		AH-1G		ALL	
	No.	λ_m*	No.	λ_m*	No.	λ_m*	No.	λ_m*	No.	λ_m*
T/R Blade	-	-	-	-	2	0.37	-	-	2	0.17
Pitch Change Mechanism	-	-	-	-	-	-	1	1.05	1	0.09
Crosshead Bearing	-	-	-	-	2	0.37	1	1.05	3	0.26
Crosshead Shear Pin	-	-	-	-	-	-	1	1.05	1	0.09
Crosshead Bearing/Fell Out	-	-	1	0.25	-	-	-	-	1	0.09
Crosshead Retaining Bolt	-	-	1	0.25	-	-	-	-	1	0.09
P/C/L Bearing	-	-	1	0.25	-	-	-	-	1	0.09
P/C/L/Worn, Caused Binding	-	-	-	-	2	0.37	1	1.05	3	0.26
P/C/L/Broke, Failed	1	0.80	-	-	-	-	-	-	1	0.09
Control Tube, Control Tube Nut or Cotter Key/Sheared, Failed	3	2.40	7	1.73	4	0.74	-	-	14	1.19
Slider/Lacked Lube	-	-	2	0.49	-	-	-	-	2	0.17
Self-Locking Nuts on P/C Shaft	-	-	-	-	1	0.18	-	-	1	0.09
T/R Control Quill Assembly	1	0.80	4	0.99	3	0.55	-	-	8	0.68
T/R Control Quill Housing	-	-	-	-	-	-	1	1.05	1	0.09
T/R Control Quill Sprocket Guard/Worn	-	-	-	-	1	0.18	-	-	1	0.09

TABLE CX. (Cont'd)

FAILED ITEM/MODE	UH-1C No.	UH-1C λ_m*	UH-1D No.	UH-1D λ_m*	UH-1H No.	UH-1H λ_m*	AH-1G No.	AH-1G λ_m*	ALL No.	ALL λ_m*
T/R Control Quill Sprocket Wheel/ Worn	-	-	-	-	1	0.18	-	-	1	0.09
T/R Control Quill Sprocket/Loose	-	-	-	-	1	0.18	1	1.05	2	0.17
T/R Control Quill Sprocket Failure	-	-	1	0.25	-	-	-	-	1	0.09
Control Chain/Broke	-	-	1	0.25	-	-	-	-	1	0.09
Control Chain/Stretched	-	-	-	-	-	-	1	1.05	1	0.09
Control Chain/Twisted	-	-	-	-	-	-	1	1.05	1	0.09
Control Chain/Failed	2	1.60	5	1.23	2	0.37	1	1.05	10	0.85
TOTAL MATERIAL FAILURES	24	19.2	52	12.84	61	11.19	38	40.04	175	14.96
TIME BASE (flight hours)	1,250,000		4,050,000		5,450,000		949,000		11,699,000	

* λ_m = Mishap rate per million flight hours

APPENDIX IV

UH-1/AH-1 TAIL ROTOR SYSTEM FAILURE MODE ANALYSIS

The tables in this appendix are the details of the failure mode analysis presented in Section 10. Included are all occurrences from the M&R program data which resulted in unscheduled maintenance on the tail rotor system.

TABLE CXI. TAIL ROTOR HUB AND BLADE FAILURE MODE ANALYSIS

Failure Mode	Failure Cause	Class of Fail. Mode	Failure Rates Per Million Flight Hours											
			UH-1D/H				UH-1C				AH-1G			
			Primary			Secondary	Primary			Secondary	Primary			Secondary
			Inherent	Induced	Combat Damage		Inherent	Induced	Combat Damage		Inherent	Induced	Combat Damage	
T/R Hub														
Safety Wire From Hub Retaining Nut to Static Stop Broken	Unknown	I	13	-	-	-	-	-	-	-	-	-	-	-
Data Plate Missing From T/R Hub/ Bond Failed	Bonding Failure	I	13	-	-	-	-	-	-	-	-	-	-	-
T/R Hub Components Corroded	Insufficient Plating	I	65	-	-	-	-	-	-	-	-	-	-	-
T/R Hub Trunnion Bearings Rough/ Worn	Normal Wear/Sandy Environment	II	39	-	-	-	-	-	-	-	-	-	-	-
T/R Grip Bearings Worn/Loose/Rough	Normal Wear/Lack of Lubrication	II	130	-	-	-	54	-	-	-	380	-	-	-
T/R Hub Spindle Fretting/Damaged/ Cracked	Fatigue	IV	-	-	-	-	-	-	-	-	73	-	-	-
T/R Hub Grease Fitting Missing/Loose	Unknown	I	-	-	-	-	-	-	-	-	44	-	-	-
T/R Grip Nut/Bearing Retainer Nut Loose	Maintenance Undertorqued	III	-	26	-	-	-	56	-	-	-	-	-	-
T/R Grip Pitch Change Bushing Worn	Securing Bolt Has Low Torque	II	-	-	-	-	-	54	-	-	-	-	-	-
T/R Hub Removed-Engine Overspeed	Engine Overspeed	N/A	-	65	-	-	-	56	-	-	-	73	-	-
T/R Hub Removed - Sudden Stoppage	Pilot Error, Tree Strike	N/A	-	143	-	-	-	-	-	-	-	29	-	-
T/R Hub Bearings Won't Take Lubrication	Thrust Unit Installed Backwards	I	-	-	-	-	-	25	-	-	-	-	-	-
T/R Hub Damaged by P/C Link	T/R P/C Link Improperly Installed	I	-	-	-	-	-	-	-	-	-	15	-	-
T/R Hub Damaged by Armament Debris	Spent Brass Strike	II	-	13	-	-	-	25	-	-	-	-	-	-
T/R Hub and Blade Lost in Flight	T/R Yoke Crack/Unknown	IV	-	-	-	-	-	-	-	-	-	29	-	-
T/R Hub Removed - Wrong Part Number	Maintenance Error	N/A	-	13	-	-	-	-	-	-	-	-	-	-
T/R Vibration	Out of Track/Balance	II	13	-	-	-	-	-	-	-	88	-	-	-
	UH-1D/H TOTAL 533 SUBTOTALS		273	260	-	-								
	UH-1C TOTAL 336 SUBTOTALS						54	252	-	-				
	AH-1G TOTAL 731 SUBTOTALS										585	146	-	-

TABLE CXI. (Cont'd)

Failure Mode	Failure Cause	Class of Fail. Mode	UH-1D/H Primary Inherent	UH-1D/H Primary Induced	UH-1D/H Primary Combat Damage	UH-1D/H Secondary	UH-1C Primary Inherent	UH-1C Primary Induced	UH-1C Primary Combat Damage	UH-1C Secondary	AH-1G Primary Inherent	AH-1G Primary Induced	AH-1G Primary Combat Damage	AH-1G Secondary
T/R Blade														
T/R Blade has Strike Damage	Contact Tree, Wire, Etc.	III	-	337	-	-	-	-	-	-	-	44	-	-
T/R Blade Has Leading-Edge Erosion	Wear, Sandy Environment	II	169	-	-	-	-	-	-	-	-	-	-	-
T/R Blade Damaged By Armament Debris	Spent Brass Strike	III	-	169	-	-	-	2393	-	-	-	256	-	-
T/R Blade Has Combat Damage	Enemy Combat Fire	III	-	-	32	-	-	-	-	-	-	-	15	-
T/R Blade Has Bonding Void	Bonding Failure	II	20	-	-	-	-	-	-	-	29	-	-	-
T/R Blade Removed - Overspeed	Overspeed - Pilot Error	N/A	-	65	-	-	-	56	-	-	22	-	-	-
T/R Blade Removed - Sudden Stoppage	Hard Landing, Engine Failure	N/A	-	39	-	-	-	-	-	-	-	58	-	-
T/R Blade Has Foreign Object Damage	Foreign Object Damage	III	-	-	-	-	-	98	-	-	7	373	-	-
T/R Blade Leading-Edge Hole Patch Loose	Bonding Failure	II	-	-	-	-	28	-	-	-	-	-	-	-
T/R Vibration	Blades Out of Track	II	32	-	-	-	168	-	-	-	80	-	-	-
Lost in Flight	Unknown	IV	-	-	-	-	-	-	-	-	7	-	-	-
	UH-1D/H TOTAL SUBTOTALS 863		221	610	32	-								
	UH-1C TOTAL SUBTOTALS 2743						196	2547	-	-				
	AH-1G TOTAL SUBTOTALS 891										145	731	15	-

TABLE CXII. TAIL ROTOR DRIVE SUBSYSTEM FAILURE MODE ANALYSIS

Failure Mode	Failure Cause	Class of Fail. Mode	Failure Rates Per Million Flight Hours											
			UH-1D/H				UH-1C				AH-1G			
			Primary				Primary				Primary			
			Inherent	Induced		Secondary	Inherent	Induced		Secondary	Inherent	Induced		Secondary
					Combat Damage				Combat Damage				Combat Damage	
<u>T/R Drive Shaft Hanger Assy</u>														
T/R D/S Hanger Assy Seal Failure	Sandy Environment, Grease Deteriorates Seal	I	91	-	-	-	9	-	-	-	63	-	-	-
T/R D/S Hanger Assy Seal Torn	Damaged During Lubrication	I	-	55	-	-	-	-	-	-	-	-	-	-
T/R D/S Hanger Coupling Seal Installed Wrong	Maintenance Error	I		3	-	-	-	9	-	-	-	-	-	-
T/R D/S Hanger Bearing Failure	Sandy Environment/Lack of Lube	II	403	-	-	-	494	-	-	-	302	-	-	-
T/R D/S Assy Removed - Sudden Stoppage	Crash, Rotor Stoppage	III	-	68	-	-	-	-	-	-	-	45	-	-
T/R D/S Hanger Assy Mount Chafing D/S Cover	Incorrect Cowling Installation	I	-	-	-	-	-	19	-	-	-	-	-	-
T/R D/S Hanger Grease Inadequate/D/S Bottoms Out	Lack of Lubrication	II	-	3	-	-	-	47	-	-	44	-	-	-
T/R D/S Hanger Assy Stack-up Improper	Maintenance Error	I	-	-	-	-	-	23	-	-	-	-	-	-
T/R D/S Hanger Assy "Thru Bolt" Loose	Suspect Bad Bearing	I	-	-	-	-	19	-	-	-	-	-	-	-
T/R D/S Hanger Assy Mount Bolt Installed Wrong	Improper Maintenance	I	-	-	-	-	-	19	-	-	-	5	-	-
No. 1 T/R D/S Hanger Assy Seal Melted/Coming Apart	Heat/Vibration from Blower Failure	I	-	-	-	-	-	-	-	-	-	-	-	29
	UH-1D/H TOTAL SUBTOTALS 623		494	129	-	-								
	UH-1C TOTAL SUBTOTALS 644						522	122	-	-				
	AH-1G TOTAL SUBTOTALS 488										409	50	-	29

TABLE CXII. (Cont'd)

Failure Mode	Failure Cause	Class of Fail. Mode	Failure Rates Per Million Flight Hours											
			UH-1D/H				UH-1C				AH-1G			
			Primary			Secondary	Primary			Secondary	Primary			Secondary
			Inherent	Induced			Inherent	Induced			Inherent	Induced		
					Combat Damage				Combat Damage				Combat Damage	
42^{o} Gearbox														
42^{o} G/B Damaged - Combat Inflicted	Enemy Fire	III	-	-	13	-	-	-	-	-	-	-	-	-
42^{o} G/B Leaking at Input Quill	Seal Deteriorated, Sandy Environment	I	246	-	-	-	168	-	-	-	350	-	-	-
42^{o} G/B Leaking at Aft Quill	Seal Deteriorated, Sandy Environment	I	26	-	-	-	-	-	-	-	15	-	-	-
42^{o} G/B Leaking at Sight Gage	Washer Deteriorated	I	26	-	-	-	56	-	-	-	-	-	-	-
42^{o} G/B Leaking at Filler Cap	Suspect Packing Deteriorated	I	13	-	-	-	28	-	-	-	-	-	-	-
42^{o} G/B Removed - Sudden Stoppage	T/R Hit Tree, M/R Sudden Stoppage	III	-	143	-	-	-	-	-	-	-	-	-	-
42^{o} G/B Drain Plug Broken	Unknown - Suspect Faulty Maintenance	I	-	-	-	-	-	28	-	-	-	-	-	-
42^{o} G/B Oil Leak at Magnetic Plug	Maintenance Mishandling, Plug Damaged	I	-	-	-	-	-	56	-	-	-	-	-	-
42^{o} G/B Mounting Bolts Loose	Maintenance Error	II	-	-	-	-	-	56	-	-	-	-	-	-
42^{o} G/B Sight Gage Broken	Unknown	I	-	-	-	-	-	-	-	-	-	29	-	-
42^{o} G/B Cracked	Unknown	III	-	-	-	-	-	-	-	-	15	-	-	-
42^{o} G/B Replaced - Hard Landing	Hard Landing	III	-	-	-	-	-	-	-	-	-	43	-	-
42^{o} G/B Filler Cap Chain Broken	Maintenance Mishandled	I	-	-	-	-	-	-	-	-	-	15	-	-
42^{o} G/B Damaged By T/R Overload	T/R Overload	III	-	-	-	-	-	-	-	-	-	423	-	-
42^{o} G/B Oil Contaminated	Unknown	II	-	-	-	-	-	-	-	-	-	29	-	-
42^{o} G/B Grease Seal Torn	Unknown	II	13	-	-	-	-	-	-	-	-	-	-	-
	UH-1D/H TOTAL 480 SUBTOTALS		324	143	13	-								
	UH-1C TOTAL 392 SUBTOTALS						252	140	-	-				
	AH-1G TOTAL 919 SUBTOTALS										380	539	-	-

TABLE CXII. (Cont'd)

Failure Mode	Failure Cause	Class of Fail. Mode	Failure Rates Per Million Flight Hours											
			UH-1D/H				UH-1C				AH-1G			
			Primary				Primary				Primary			
			Inherent	Induced		Secondary	Inherent	Induced		Secondary	Inherent	Induced		Secondary
					Combat Damage				Combat Damage				Combat Damage	
90° Gearbox														
90° G/B Filler Cap Chain Broken	Suspect Maintenance Error	I	-	13	-	-	-	28	-	-	-	219	-	-
90° G/B Case Stud Sheared	Maintenance Overtorque	II	-	13	-	-	-	-	-	-	-	-	-	-
90° G/B Components Corroded	Suspect Poor Plating	I	40	-	-	-	-	-	-	-	-	-	-	-
90° G/B Oil Contaminated/Water Grease	Improper Washdown Procedure, Cap Left Off, Excess Grease	I	-	75	-	-	-	196	-	-	-	44	-	-
90° G/B Has Metal Particles on Magnetic Plug	Unknown - Suspect Internal Wear	III	65		-	-	84	-	-	-	365	-	-	-
90° G/B Leaking at Input Quill	Seal Deterioration, Sandy Environment	I	143	-	-	-	56	-	-	-	234	-	-	-
90° G/B Leaking at Output Quill	Seal Deterioration, Sandy Environment	I	91	-	-	-	56	-	-	-	102	-		-
90° G/B Leaking at Sight Gage	Sight Gage Washer Deteriorates	I	40	-	-	-	-	-	-	-	29	-	-	-
90° G/B Leaking at Filler Cap	Cap Improperly Tightened, Packing Damaged, Maintenance Error	I		13	-	-		252	-	-		44	-	-
90° G/B Mounting Nuts Loose	Vibration	II	13	-	-	-	-	-	-	-	-	-	-	-
90° G/B Removed - Sudden Stoppage	Tree Strike, Pilot Error	III	-	156	-	-	-	-	-	-	-	-	-	-
90° G/B Oil Level Sight Gage Glass Discolored	Sand, Wind, Oil Contaminated	I	-	40	-	-	-	84	-	-	-	-	-	-
90° G/B Leaking at Chip Detector	Damaged by Maintenance	I	-	-	-	-	-	56	-	-	-	-	-	-
90° G/B I/P Quill Has Inadequate Lube, D/S Bottoms Out	Lack of Lube	II	-	-	-	-	224	-	-	-	-	-	-	-
90° G/B Case Chafed By G/B Cover	Improper Cover Fit	I	-	-	-	-	-	-	-	-	-	44	-	-
90° G/B Chain Chafes Cover	Improper Installation	I	-	-	-	-	-	-	-	-	-	15	-	-
90° G/B Filler Neck Chipped	Unknown	I	-	-	-	-	-	-	-	-	-	15	-	-
90° G/B Cracked	Preloaded Mounting Position	III	-	-	-	-	-	-	-	-	-	44	-	-
90° G/B Replaced/Lost in Flight	Suspect T/R Hub Failure	III	-	-	-	-	-	-	-	-	-	-	-	102

TABLE CXII. (Cont'd)

Failure Mode	Failure Cause	Class of Fail. Mode	Failure Rates Per Million Flight Hours											
			UH-1D/H				UH-1C				AH-1G			
			Primary			Secondary	Primary			Secondary	Primary			Secondary
			Inherent	Induced			Inherent	Induced			Inherent	Induced		
					Combat Damage				Combat Damage				Combat Damage	
90° Gearbox (Cont'd)														
90° G/B Has Combat Damage	Enemy Fire	III	-	-	-	-	-	-	-	-	-	-	29	-
90° G/B Damaged Internally	T/R Overload	III	-	-	-	-	-	-	-	-	-	975	-	-
	UH-1D/H TOTAL 705 SUBTOTALS		392	313	-	-								
	UH-1C TOTAL 1036 SUBTOTALS						420	616	-	-				
	AH-1G TOTAL 2264 SUBTOTALS										730	1403	29	102
T/R Drive Shaft														
T/R D/S Corroded	Improper Maintenance, Aircraft Cleaning Soap	I	-	26	-	-	-	-	-	-	-	-	-	-
T/R D/S Dented or Damaged	Blade Strike/Hard Landing/Unknown	II	-	17	-	-	-	22	-	-	-	58	-	-
T/R D/S or Clamps Damaged	Tools Left Under D/S Cover, Rough Handling	II	-	9	-	-	-	11	-	-	-	61	-	-
T/R D/S Has Combat Damage	Enemy Fire	III	-	-	6	-	-	-	6	-	-	-	12	-
T/R D/S Clamp Loose/Misaligned/ Cracked	Improperly Installed	III	-	19	-	-	-	-	-	-	-	26	-	-
T/R D/S Removed - Sudden Stoppage	T/R Blade Hit Tree	III	-	15	-	-	-	-	-	-	-	21	-	-
T/R D/S or Clamps Damaged	Chafed by Adjacent Parts	I	-	-	-	-	-	-	-	-	-	49	-	-
T/R D/S Clamp Damaged	Unknown	II	6	-	-	-	39	-	-	-	-	-	-	-
	UH-1D/H TOTAL 98 SUBTOTALS		6	86	6	-								
	UH-1C TOTAL 78 SUBTOTALS						39	33	6	-				
	AH-1G TOTAL 257 SUBTOTALS										-	245	12	-

TABLE CXIII. TAIL ROTOR CONTROL SUBSYSTEM FAILURE MODE ANALYSIS

Failure Mode	Failure Cause	Class of Fail. Mode	Failure Rates Per Million Flight Hours											
			UH-1D/H				UH-1C				AH-1G			
			Primary			Secondary	Primary			Secondary	Primary			Secondary
			Inherent	Induced			Inherent	Induced			Inherent	Induced		
					Combat Damage				Combat Damage				Combat Damage	
T/R Boot														
T/R Installation Boot Torn or Cut	Rough Handling, Maintenance Error	II	-	298	-	-	-	168	-	-	-	1036	-	-
T/R Boot Loose	Unknown	II	-	-	-	-	-	-	-	-	44	-	-	-
T/R Boot Removed - Sudden Stoppage	T/R Strike		-	26	-	-	-	-	-	-	-	-	-	-
	UH-1D/H TOTAL SUBTOTALS 324		-	324	-	-								
	UH-1C TOTAL SUBTOTALS 168						-	168	-	-				
	AH-1G TOTAL SUBTOTALS 1080										44	1036	-	-
T/R Slider														
T/R Slider Worn	Normal Wear, Sandy Environment	II	363	-	-	-	979	-	-	-	497	-	-	-
Slide Removed - Sudden Stoppage	T/R Strike		-	26	-	-	-	-	-	-	-	-	-	-
	UH-1D/H TOTAL SUBTOTALS 389		363	26	-	-								
	UH-1C TOTAL SUBTOTALS 979						979	-	-	-				
	AH-1G TOTAL SUBTOTALS 497										497	-	-	-
Crosshead Bearing Set														
Bearing Set Worn/Separating	Sandy Environment, Lack of Lube	II	207	-	-	-	140	-	-	-	204	-	-	-
Bearing Set Loose	Improper Installation	II	-	52	-	-	-	-	-	-	-	-	-	-
Bearing Set Removed	T/R Strike	N/A	-	26	-	-	-	-	-	-	-	-	-	-
	UH-1D/H TOTAL SUBTOTALS 285		207	78	-	-								
	UH-1C TOTAL SUBTOTALS 140						140	-	-	-				
	AH-1G TOTAL SUBTOTALS 204										204	-	-	-

TABLE CXIII. (Cont'd)

Failure Mode	Failure Cause	Class of Fail. Mode	Failure Rates Per Million Flight Hours: UH-1D/H Primary Inherent	UH-1D/H Primary Induced	UH-1D/H Primary Combat Damage	UH-1D/H Secondary	UH-1C Primary Inherent	UH-1C Primary Induced	UH-1C Primary Combat Damage	UH-1C Secondary	AH-1G Primary Inherent	AH-1G Primary Induced	AH-1G Primary Combat Damage	AH-1G Secondary
T/R Crosshead														
T/R Crosshead and Attaching Bolt Corroded	Insufficient Plating	II	13	-	-	-	-	-	-	-	-	-	-	-
T/R Crosshead Assembly Scored by P/C Link Bearing	Improper Alignment	II	-	117	-	-	-	-	-	-	-	234	-	-
Loss of Torque on Crosshead Retaining Nuts	Undertorqued, Maintenance	II	-	13	-	-	-	-	-	-	-	-	-	-
T/R Crosshead Assy Removed - Sudden Stoppage	Tree Strike (T/R)	III	-	13	-	-	-	-	-	-	-	-	-	-
Crosshead Improperly Shimmed	Maintenance Error	II	-	91	-	-	-	-	-	-	-	-	-	-
T/R Crosshead Loose - High Frequency Vibration	Bushing Worn, Misaligned	II	13	-	-	-	-	-	-	-	160	-	-	-
	UH-1D/H TOTAL 260 SUBTOTALS		26	234	-	-								
	AH-1G TOTAL 394 SUBTOTALS						-	-	-	-	160	234	-	-
T/R Chain														
T/R Chain Worn	Sand Contamination, Oil, Dust	II	428	-	-	-	56	-	-	-	715	-	-	-
T/R Chain Has Frozen Links	Sand Contamination	II	26	-	-	-	25	-	-	-	-	-	-	-
T/R Chain Dirty	Sand Contamination	II	-	-	-	-	-	28	-	-	-	-	-	-
T/R Chain Twisted/Pedals Binding	Unknown	II	65	-	-	-	-	-	-	-	15	-	-	-
T/R Chain Removed - Sudden Stoppage	T/R Strike	III	-	-	-	-	-	-	-	-	-	15	-	-
	UH-1D/H TOTAL 519 SUBTOTALS		519	-	-	-								
	UH-1C TOTAL 112 SUBTOTALS						84	28	-	-				
	AH-1G TOTAL 745 SUBTOTALS										730	15	-	-

TABLE CXIII. (Cont'd)

Failure Mode	Failure Cause	Class of Fail. Mode	Failure Rates Per Million Flight Hours											
			UH-1D/H				UH-1C				AH-1G			
			Primary				Primary				Primary			
			Inherent	Induced			Inherent	Induced			Inherent	Induced		
					Combat Damage	Secondary			Combat Damage	Secondary			Combat Damage	Secondary
T/R Control Quill Assy														
T/R Control Quill Binding	Sand & Dirt in Bearing	II	195	-	-	-	165	-	-	-	70[illegible]	-	-	-
Excess Play in T/R Control Quill	Lack of Lube, Teeth Worn	II	52	-	-	-	-	-	-	-	-	-	-	-
T/R Control Quill Leaking	Improper Packing	II	-	91	-	-	-	25	-	-	73	-	-	-
T/R Control Quill Binding	Improper Rigging	III	-	-	-	-	-	-	-	-	-	15	-	-
Quill Removed - Sudden Stoppage	T/R Strike	III	-	39	-	-	-	-	-	-	-	15	-	-
	UH-1D/H TOTAL SUBTOTALS 377		247	130	-	-								
	UH-1C TOTAL SUBTOTALS 1[illegible]						165	25	-	-				
	AH-1G TOTAL SUBTOTALS [illegible]04										774	30	-	-
T/R Control Tube														
Splines Worn on T/R Control Tube	Overtorque - Maintenance Error	II	-	52	-	-	-	25	-	-	-	-	-	-
Torque Low on T/R Retaining Nut	Undertorque - Maintenance Error	III	-	26	-	-	-	-	-	-	-	-	-	-
Threads Stripped on T/R Control Tube or Nut	Maintenance Error	III	-	117	-	-	-	-	-	-	-	73	-	-
Removed - Sudden Stoppage	T/R Strike	III	-	26	-	-	-	-	-	-	-	-	-	-
	UH-1D/H TOTAL SUBTOTALS 221		-	221	-	-								
	UH-1C TOTAL SUBTOTALS 25						-	25	-	-				
	AH-1G TOTAL SUBTOTALS 73										-	73	-	-

TABLE CXIII. (Cont'd)

Failure Mode	Failure Cause	Class of Fail. Mode	Failure Rates Per Million Flight Hours											
			UH-1D/H				UH-1C				AH-1G			
			Primary				Primary				Primary			
			Inherent	Induced		Secon-dary	Inherent	Induced		Secon-dary	Inherent	Induced		Secon-dary
					Combat Damage				Combat Damage				Combat Damage	
T/R Pitch Change Link														
T/R P/C Link Bearings Worn	Sandy Environment, Lack of Lube	II	765	-	-	-	350	-	-	-	911	-	-	-
T/R P/C Link Bearings Frozen	Sandy Environment	II	13	-	-	-	-	-	-	-	-	-	-	-
Teflon Liner Separation in T/R P/C Link Bearing	Bond Failure	II	39	-	-	-	-	-	-	-	-	-	-	-
T/R P/C Link Bearing Outer Race Corroding	Unknown	II	7	-	-	-	-	-	-	-	-	-	-	-
T/R P/C Link Assy Out of Alignment	Maintenance Error	II	-	39	-	-	-	-	-	-	-	37	-	-
T/R P/C Link Replaced, Nut Frozen	Bolt Corrosion	II	-	-	-	13	-	-	-	-	-	-	-	-
T/R P/C Link Rivet Sheared	Maintenance Error	II	-	-	-	-	-	14	-	-	-	15	-	-
T/R P/C Link Stack-up Improper	Maintenance Error	II	-	-	-	-	-	98	-	-	-	-	-	-
T/R P/C Link Rod Bent/Threads Stripped	Unknown-Suspect Overload	III	-	-	-	-	56	-	-	-	-	15	-	-
T/R P/C Link Bearing Chafes T/R Crosshead	Bearing Worn	II	-	-	-	-	-	-	-	-	44	-	-	-
T/R P/C Link Bearing Inner Race Cracked	Unknown	II	-	-	-	-	-	-	-	-	22	-	-	-
T/R P/C Link Damaged/Hard Landing	Pilot Error	III	-	39	-	-	-	-	-	-	-	7	-	-
T/R P/C Link Jam Nut Loose	Maintenance Error	II	-	-	-	-	-	-	-	-	-	15	-	-
	UH-1D/H TOTAL 915 SUBTOTALS		824	78	-	13								
	UH-1C TOTAL 518 SUBTOTALS						406	112	-	-				
	AH-1G TOTAL .066 SUBTOTALS										977	89	-	-

APPENDIX V

TAIL ROTOR HUB AND BLADE ASSEMBLY MAINTENANCE PROCEDURES DIRECT/GENERAL SUPPORT LEVELS 27, 28, 29

Model UH-1D/H

A. Tail Rotor Blades

NOTE

The special tools required to perform maintenance functions of the tail rotor hub and blade are listed below:

Special Tools Required

PART NUMBER	NOMENCLATURE
T101412	Grip Spacing Tool
T101407	Seal Bearing Tool
7HEL065	Kit, Blade Balancing
7AU50	Kit, Blade Balancing
7HEL0153	Kit Balancing

1. Removal

a. Remove hub and blade assembly. (Refer to Appendix I, Page 149.)

NOTE

Observe and note color coding on blades and grips.

b. Remove nuts, washers, and bolts attaching tail rotor blades to blade grips, and remove blades.

c. Loosely install bolts, washers, and nuts in grips as removed, if same blades and hub are to be reassembled. If blades or hub are to be replaced, bolts, washers, and nuts need not be saved.

2. Repair or Replacement - Tail Rotor Blades. (Refer to Appendix I, page 149.)

a. Inspect blades according to the following criteria:

NOTE

Tail rotor blades damaged to the following extent should be "condemned and demilitarized" locally rather than returned to an overhaul facility.

(1) Water in the honeycomb area.

(2) Any blade that has reached maximum service life or has less than 200 hours remaining service time.

(3) If one or more cracks develop and extend from a previously repaired area.

(4) Holes in the skin larger in area than allowed for patching.

(5) Any corrosion that penetrates entirely through the skin larger in area than allowed for patching.

(6) If the abrasive strip is worn completely through at the tip.

(7) Edge voids deeper than 0.50 inch at the tip end of any of the root end doublers or grip plates.

(8) Edge voids in the leading edge or trailing edge of the doublers that are 0.25 inch or more in depth and show indications of corrosion in the void.

(9) Any crack in any location in the main bonded part of the blade unless within area of allowable patches and within limits. (See NOTE under Paragraph A.3.e.)

(10) Bond separations on any part of the blade.

NOTE

A void is defined as an unbonded area that is normally bonded. Many sub-definitions of voids are given,

such as lack of adhesive, gas pocket, misfit, etc. This manual shall make no distinction among these, but shall group them in the one general term, Void. All dimensions are in inches.

WARNING

If one blade of a pair has been damaged badly enough that metal has been torn or any bond lines have separated, both blades must be replaced.

(11) Movement of the tip or root end weights.

(12) Cracks or dents in the abrasion strip unless within area of allowable patches and within limits.

b. Replacement of blade is necessary if the following defects or damage is found.

NOTE

Refer removed blades to higher maintenance activity for evaluation.

(1) Void exceeding 0.25 inch wide between the abrasive strip and the inner doubler along the centerline.

(2) Edge voids in any single bond line at the butt end around the edges and the grip plates exceeding 10% of the total periphery of that bond line. Single-edge void exceeding 0.06 inch in depth by 2.0 inches in length.

(3) Void between skin and trailing edge under the doubler rear "fingers" at the butt end.

(4) Void between skin and inner doubler under the front "fingers" at the butt end.

(5) Void between the tip block and the trailing-endge extrusion.

(6) Void between skins and trailing edge at the tip in the outboard 1.0 inch.

(7) Void in the blade body between the ends of the blade between the skin and the core exceeding 0.20 inch wide chordwise by 0.50 inch long spanwise or if spacing between centers is less than 2.0 inches.

(8) Void in the blade body between the ends of the blade between the skin and the inner doubler exceeding 0.50 inch wide chordwise by 1.0 inch long spanwise or if spacing between centers is less than 3.0 inches.

(9) Void in the blade body between the core and the inner doubler exceeding 0.50 inch chordwise by 1.5 inches spanwise or if centers are less than 3.0 inches.

(10) Looseness of either retention bolt hole bushing.

(11) Inside diameter of retention bolt hole bushing exceeds 0.4380 inch.

NOTE

Any void not specified in paragraphs (1) through (11) will require blade replacement.

(12) Sudden stoppage or overtorquing.

(13) Blades that have been subjected to an overspeed condition that do not meet limits of Special Inspection.

c. Repair Tail Rotor Blades

NOTE

Installation of blade on grip or removal from grip must be performed by direct support maintenance activity.

CAUTION

Damage exceeding the limits of steps (1) through (4) requires replacement of blade.

(1) Polish out all nicks and scratches on the surface of the blade that are 0.008 inch deep or less using abrasive cloth (180 grit or finer). Polish to a surface finish of 63 RMS or better, removing only enough material to remove scratch or nick. Aluminum wool may be used on aluminum surfaces, and steel wool may be used on the abrasive strip to polish out defects.

(2) Polish out nicks and notches in the extreme trailing edge of the blade that are 0.050 inch or less in depth to a distance of at least 2.0 inches on each side of the nick or notch using abrasive cloth. Depth of polishing to be minimum necessary to clean up all evidence of the nick or notch.

(3) Polish out all nicks or scratches in dents that are 0.008 or less in depth using abrasive cloth (180 grit or finer). Polish to a surface finish of 63RMS or better, removing only enough material to remove the nick or scratch. Aluminum wool may be used on aluminum surfaces, and steel wool may be used on the abrasive strip to polish out defects.

(4) Polish out pits not exceeding 0.008 inch in depth using abrasive cloth (600 grit) or aluminum wool, rubbing spanwise to remove sanding marks. Finish to 32 RMS or better.

d. Repair and Touch Up Blades

(1) Burnish out any scratches which are within allowable limits. (Refer to Paragraph C)

(2) Burnish out any pits which are within allowable limits. (Refer to Paragraph C)

(3) If entire blade is to be refinished, strip paint from area to be refinished using methyl-ethyl-ketone.

CAUTION

DO NOT IMMERSE BLADES IN STRIPPING SOLUTION. Use ONLY methyl-ethyl-ketone for stripping finish from blades to prevent damage to adhesive bonded areas.

(4) Plug the retention bolt holes to prevent entry of finishing materials.

(5) Remove all surface oxides and chemical conversion coatings using Scotchbrite from all bare aluminum surfaces.

(6) Wash blade using cleaning compound. Achieve water-breakfree surface which will be evident by continuous unbroken film of water on the surface after thoroughly rinsing all traces of cleaning compound from the surface.

NOTE

Following achievement of water breakfree surface through final paint, do not touch blade with bare hands.

(7) Spray or brush a solution of alodine on all bare aluminum surfaces.

(8) Apply one coat of primer to the touch-up areas only, and allow to air-dry a minimum of 30 minutes and a maximum of 4 hours.

NOTE

If primer is allowed to dry more than 4 hours before the first coat of lacquer, the lacquer will not adhere properly.

(9) Apply one coat of lacquer and allow to dry 1 hour.

(10) Apply second coat of lacquer and allow to dry 1 hour.

(11) Apply one coat of lacquer to tip area and allow to dry 1 hour.

(12) Apply second coat of lacquer to tip area and allow to dry 1 hour.

(13) Air-dry blade 3 hours before handling, and dry a total of 48 hours before flying.

NOTE

If a fast cure is desired, air-dry part for 1 hour, followed by an oven-dry at 180° to 190°F for 1 hour. Finish will then be completely cured.

(14) Remove the plugs from the retention holes.

(15) Apply a coating of corrosion preventive to the inside surface of the bushings.

e. Patch Repairs - Tail Rotor Blades

NOTE

Scratches, nicks, dents, gouges, holes or other damage to the skin of the tail rotor blade that exceed allowable limits that are in the outboard of station 34.0 but 1.75 inches minimum inboard of the blade tip, 1.0 inch minimum forward of trailing edge of the blade, and 1.0 inch aft of the aft end of abrasive strip may be repaired by patching and returned to service.

(1) Remove all the paint in the area to be

patched using abrasive cloth (120 grit). Polish area using abrasive cloth (250 grit).

(2) Cut out the defect using a hole saw or by scribing through the skin with a sharp instrument. The maximum cutout must not exceed 1.50 inch in diameter.

(3) Remove skin in the cutout area, disturbing the core as little as possible. It is desirable to heat the cutout disk to 200°F maximum and to lift out the disk of skin while heated.

(4) Deburr the edges of the hole, making sure the skin is free of scratches and nicks.

(5) Prepare a patch of aluminum alloy. The patch must be large enough to overlap at least 0.75 inch around the perimeter of the hole.

(6) Using fine abrasive cloth, polish the side of the patch that will be bonded.

(7) Wipe the patch and the surface around the hole in the blade with a clean cloth dampened with methyl-ethyl-ketone. Wipe dry with a clean cloth.

CAUTION

Do not allow methyl-ethyl-ketone to enter the blade.

(8) Apply adhesive to bond areas of the patch and blade.

(9) Apply the patch to the blade. Move the patch slightly back and forth while applying pressure to expel air pockets in the adhesive. Blend out excess adhesive into surrounding area.

(10) The patch may be held in place, while

curing, with rubber bands made from an inner tube, or by other mechanical means. If epon 934 is used, cure at 75°F minimum for 5 days, or at 180°F for 60 minutes. If using metalset A4, cure at 70° to 90°F for 24 hours, or at 145°F to 155°F for 30 minutes.

(11) Refinish the area.

3. Preparation of Repairable Blades for Shipment

a. Remove foreign matter from entire exterior blade surfaces using cheesecloth or clean rags dampened with naphtha.

b. Tape all holes in the blade surface to protect interior of the blade.

c. Apply a coating of wax to all exterior surfaces of the blade except the retention bolt holes. If wax is not available, coat entire exterior surface of the blade with oil or grease.

d. Apply a light coat of grease to retention bolt holes.

e. Place blade in shipping container.

WARNING

Include detail records to simplify overhaul requirements (Form DA 2410 - Component Removal and Repair/Overhaul Record) in container.

4. Installation of Tail Rotor Blades in Grips

a. Clean paint or foreign material out of blade holes in grips and blades.

NOTE

Observe color coding on blades and grips.

CAUTION

Do not attempt to align bolt holes by striking the blade with any tool. Back up the grip at the bolt hole with a wooden block while carefully tapping bolts into place.

NOTE

Coat bolts with corrosion inhibitor before installation.

b. Insert blade into grip with leading edge of blade on same side of grip as pitch horn. Align one bolt hole and install bolt, washers, and nut.

c. Align second bolt hole and install bolt, washers, and nut in the same manner. Torque bolts 270 to 300 inch-pounds adjacent to grip bushings.

NOTE

Blade bolts may be installed with heads either inboard or outboard, but all four bolts must be installed the same.

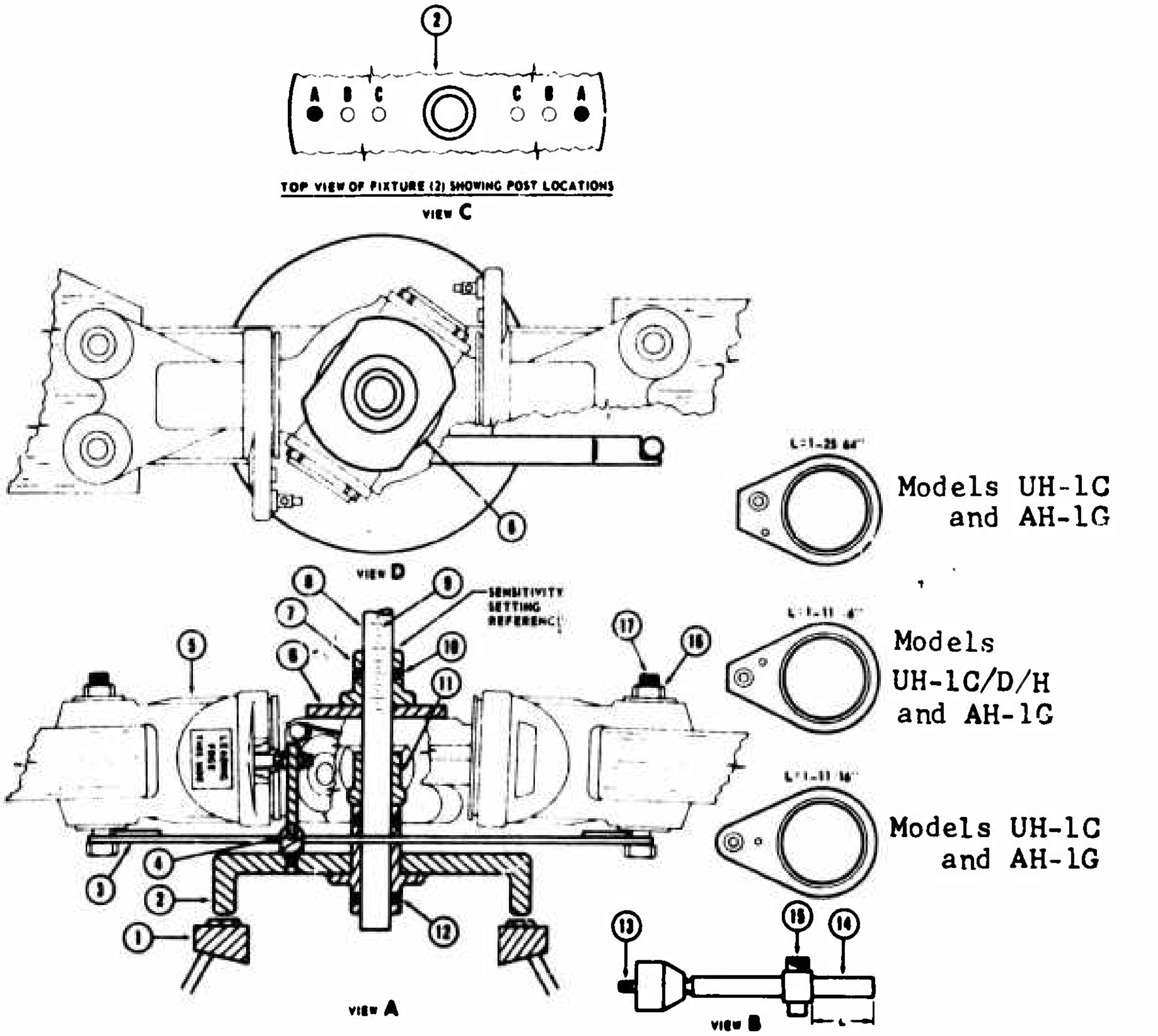
d. Repeat steps a through c to install opposite tail rotor blade.

e. Balance tail rotor hub and blade assembly. (See Paragraph B)

f. Install and rig tail rotor. (Refer to Appendix I, page 150)

B. Balancing Tail Rotor Assembly

1. Assemble workstand and hoist kit 7A050 (Figure 11). Place fixture (2) recessed side downward on table of stand as shown in view A.



1. Stand Table (7A050 Kit)
2. Fixture Assembly (2532, 7HEL0153 Kit)
3. Bar Pair (11 sets) 2940 thru 2950, 7HEL065 Kit)
4. Post Assembly (2) (2939, 7HEL0153 Kit)
5. Tail Rotor Hub and Blade Assembly
6. Plate, Special Tool (2586, Procure)
7. Bushing (2533, 7HEL0153 Kit)
8. Balancing Arbor (2516, 7HEL0153 Kit)
9. Arbor Scale
10. Bushing Set Screw
11. Pilot Bushing (2529, 7HEL0153 Kit)
12. Lower Fixture Set Screw
13. Post Thread
14. Movable Index Section
15. Index Pin-Set Screw
16. Tail Rotor Attaching Nuts
17. Tail Rotor Attaching Bolts

Figure 11. Balancing - Tail Rotor Hub and Blade, Models UH-1C/D/H and AH-1G.

NOTE

If workstand is not available, auxiliary support blocks may be used to act as a support stand.

2. Prior to installing post assemblies (4), adjust movable index pin (15) of the positioning post to a dimension of 1-11/16 inch (length L in view B). Tighten the locking set screw in index pin (15) using 3/32-inch hex wrench to maintain proper setting.

3. After adjusting post assemblies properly, install post assemblies (4) into holes of fixture (2), shown as holes A in fixture (view C).

4. Locate pilot bushing (11) large end down, centrally on top of fixture bulb.

5. Remove or loosen nuts (16) from tail rotor blade attaching bolts (17). Drive bolts partially out of yoke assembly to obtain an approximate 9/32-inch gap under bolt heads as shown in view A.

6. Set tail rotor on fixture (2) so that blade shanks clear posts (4); flat surface of hub is upward, and inside diameter of rotor splined trunnion fits over diameter of pilot bushing (11).

7. Install bushing (7), flange end downward, on balancing arbor (8) so that top surface of bushing aligns with 7-1/4-inch or 7-3/8-inch position on arbor scale (9), depending on the yoke configuration. Lock bushing in this position by moderate and uniform tightening of bushing set screws (10), using 3/32-inch hex wrench.

8. Place plate (6) centrally on top surface of rotor hub as shown in top view of assembly, and insert lower end of balancing arbor (8) downward through plate (6), bushing (11), and hub of fixture (2). Seat assembly firmly together by pressing downward on bushing (7), and lock in this position by moderate and uniform tightening of two lower fixture set screws (12).

9. Rotate the rotor hub on fixture, positioning the

index pins (15) of the two post assemblies (4) until the indexing pins enter pitch linkage holes in grip arms to their full depth.

10. From the matched sets of positioning bars (3) (P/N 2940 thru 2950, 7HEL065 kit), select the pair (set) identified as having the lowest part number (2940). Make sure each bar bears the same matched pair serial number and the same part number. Trial install the matched set of bars, blocks upward, between opposite blade attachment bolts, contacting shanks underneath the bolt heads. If bars are short, continue the trial installation using increasingly longer bar sets as necessary until the longest matched pair that can be installed between the bolts without force has been established. Once this set and length have been established, select the next higher part number bar pair. This is the matched pair bar set that shall be used during the balance operations. Be certain that the pair is identified correctly.

11. Carefully lift upward on both rotor blades at the tips simultaneously to produce increase span distance between the blade bolts; install the properly matched pair of bars described in Paragraph 10 above. Then, release blade tips, allowing bolts to rest firmly on bar ends. Move bars into final position by pressing upward to seat block sections against rotor grip bushing face surface and inward to set tang of bars against bolts. See view D.

12. Check to make sure that the positioning post index sections are engaged in grip pitch arm holes and that the arbor (8) with bushing (7) is tight against the rotor hub.

13. Sight beneath the rotor hub across the positioning bars (3) to make sure they are in the same plane. Correct, if required, by readjusting the index section of each positioning post on its mounting rod and equal mount.

14. Install quick-disconnect coupling (7HEL053 kit or 7A050 kit) on arbor suspension coupler, and suspend entire assembly free of interference. Note balance condition indicated by black indicator disc at top of balancing arbor.

NOTE

Balancing must be done in an absolutely draftless area. A maximum of six washers of any combination is allowed on each bolt. Do not remove or rework blade assembly weights. Use a combination of AN960-716 and -716L, 204-011-708-1 and 204-011-708-3 washers, with heaviest washers next to grip. Use bolts AN177-35A (minimum length) to AN177-40A (maximum length) to accommodate balance washers.

15. Balance blades chordwise and spanwise by adding washers to one or more of the blade grip bolts until the indicator bushing is as near center as possible.

C. Tail Rotor Hub Assembly. (P/N 204-011-801)

1. Description

a. Tail rotor hub assembly, Part No. 204-011-801, has a production effectivity on UH-1H helicopters Serial No. 68-16050 and subsequent.

b. It will also be supplied as all future spares and will eventually, through attrition, become effective on all UH-1 series helicopters.

c. This hub is delta-hinge mounted on a trunnion which is splined for mounting on the gearbox output shaft.

d. The hub utilizes a grooved yoke and split cone arrangement inboard of the retaining nuts to hold the pitch change bearings in place and to route the centrifugal and oscillatory loads into the yoke at the groove rather than at the retaining nut threads.

e. A preload spring assembly is provided to maintain hub and blade alignment in the static condition.

2. Disassembly

a. Secure hub assembly in vise, using T101412 as a holding fixture. Secure with flat side of yoke down.

b. Cut lockwire and remove screws (2, Figure 12), washers (3), and lockplate (4) from grip assembly (1).

c. Back off adapter nut (22) and remove grip assembly (1).

d. Remove shim (5).

e. Remove plug (6) and shims (7) from spring assembly (8).

f. Remove spring assembly (8) from yoke (24).

g. Disassemble spring assembly (8) by removing cotter pin (9), pin (10), and washers (11) from case (12).

NOTE

Tag Belleville washers (11) as removed for reassembly in the same position. A total of 42 washers, consisting of 14 stacks of three washers per stack, are required.

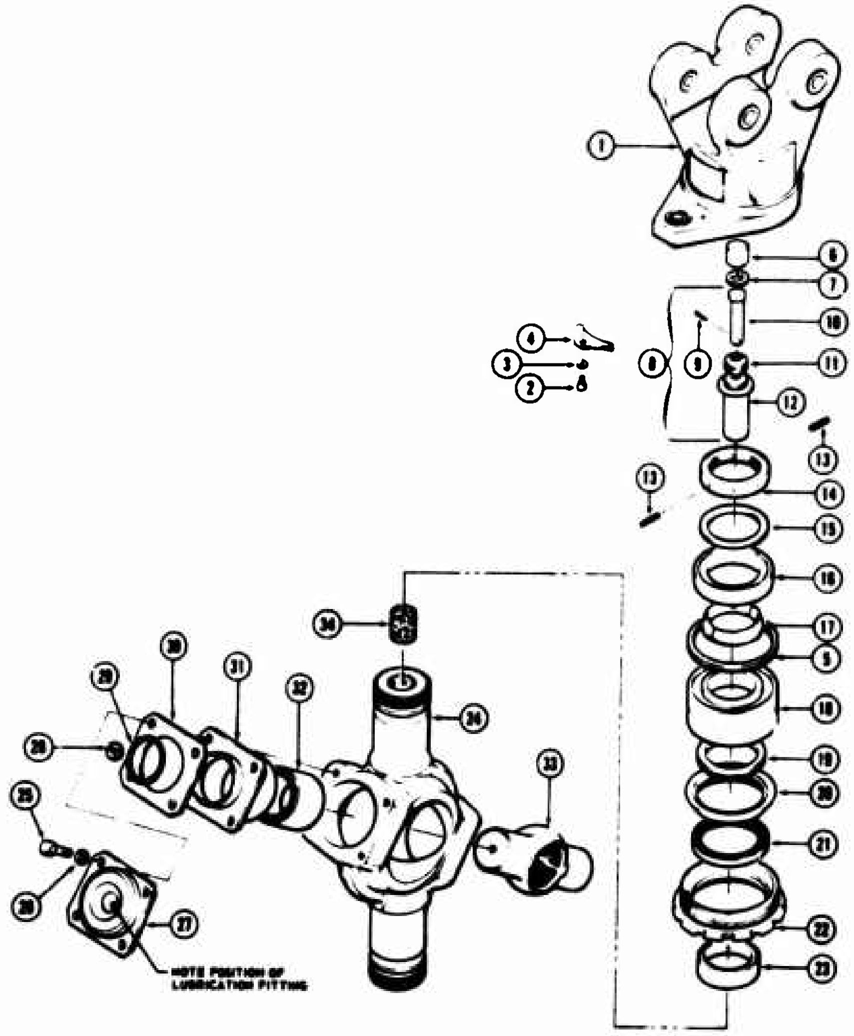
h. Cut lockwire from around nut (14). Remove two spring pins (13) and remove nut from yoke (24).

i. Remove shim (15), ring (16), split cone (17), bearing set (18), shim (19) and spacer (20).

NOTE

Keep bearing set (18) and shims (19) together as a set for reassembly on same spindle of yoke.

j. Remove seal (21) from spacer (20).



1. Grip Assembly
2. Screw
3. Washer
4. Lockplate
5. Shim
6. Plug
7. Shim
8. Spring Assembly
9. Cotter Pin
10. Pin
11. Washers
12. Case
13. Spring Pin
14. Nut
15. Shim
16. Ring
17. Split Cone
18. Bearing Set
19. Shim
20. Spacer
21. Seal
22. Adapter Nut
23. Radius Ring
24. Yoke
25. Bolt
26. Washer
27. Thrust Cap
28. Thrust Washer
29. Packing
30. Shim
31. Housing
32. Bearing
33. Trunnion
34. Cork Seal

Figure 12. Tail Rotor Hub Assembly (P/N 204-011-801), Models UH-1C/D/H.

k. Remove adapter nut (22) and radius ring (23) from spindle of yoke (24).

l. Repeat steps (b) through (k) for disassembly of parts from opposite yoke spindle.

m. Cut lockwire and remove four bolts (25), washers (26), and thrust cap (27).

n. Remove thrust washer (28), packing (29), and shim (30).

o. Remove housing (31). Use seal bearing tool, T101407, to press bearing (32) from housing.

p. Repeat steps (m) through (o) to remove parts from opposite side of yoke.

q. Remove hub assembly from holding fixture and remove trunnion from yoke.

3. Cleaning

a. Clean all parts with cleaning solvent.

b. Dry with filtered compressed air.

4. Inspection

a. Visually inspect all components for damage, excessive wear, or corrosion. (See Figures 12-15)

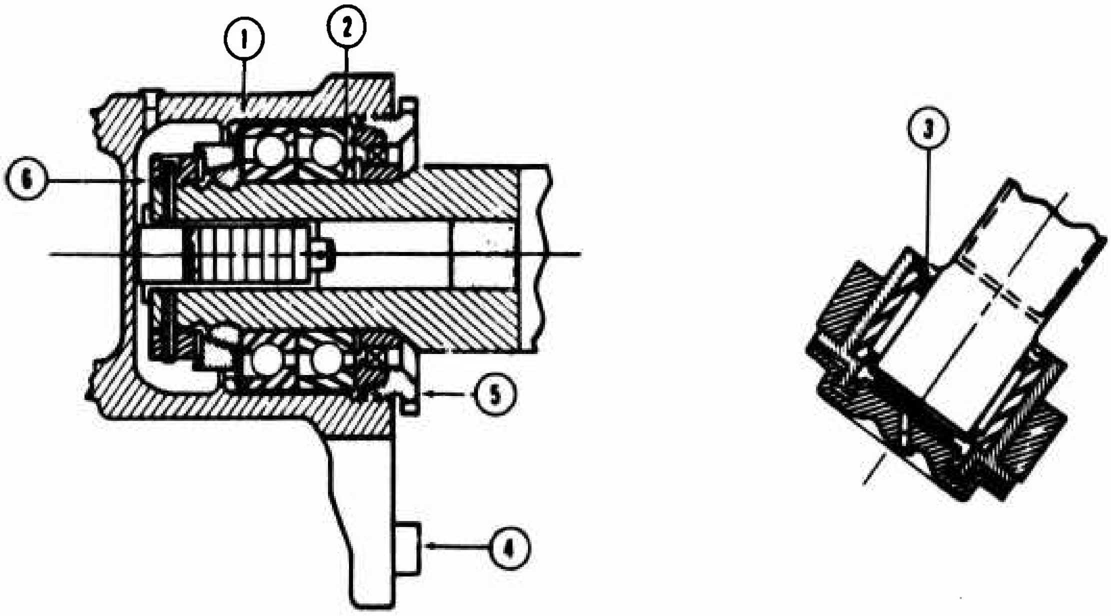
NOTE

Any nicks, scratches, and sharp dents not exceeding the maximum damage limits will be dressed and blended into the surrounding areas.

b. Check bearings for smooth operation.

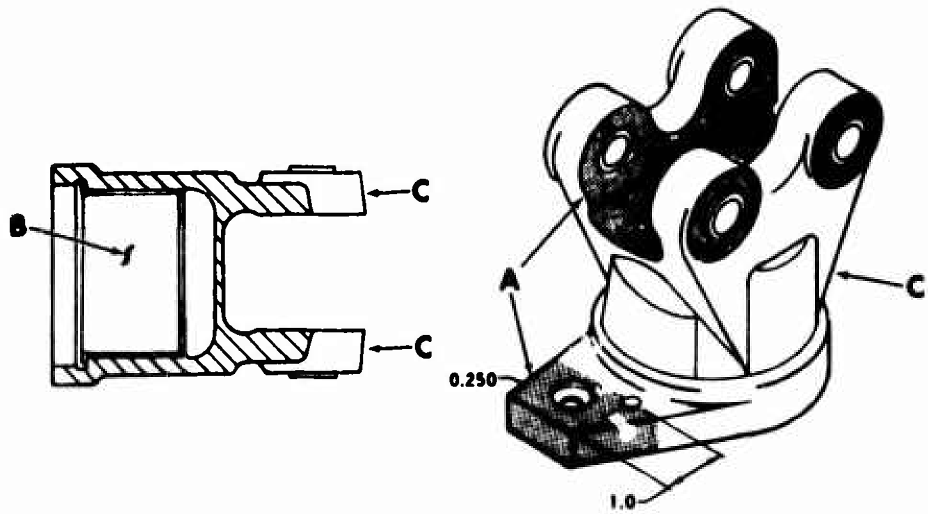
c. Inspect splines in trunnion for chipped or worn teeth.

d. Inspect all components dimensionally for excessive wear. (Figure 13)



ITEM	NOMENCLATURE		MIN.	MAX.	REPLACE
1	Grip Liner	ID	2.4410	2.4415	2.4425
2	Yoke, Bearing Seat	OD	1.3771	1.3780	1.3750
3	Trunnion Spindle	OD	1.1246	1.1250	1.1230
4	Bushing, Pitch Link	ID	0.2495	0.2500	0.2525
			TORQUE		
5	Nut	In. Lb.	500	600	
6	Nut	In. Lb.	100	125	

Figure 13. Tail Rotor Hub Limits (P/N 204-011-801), Model UH-1D/H.

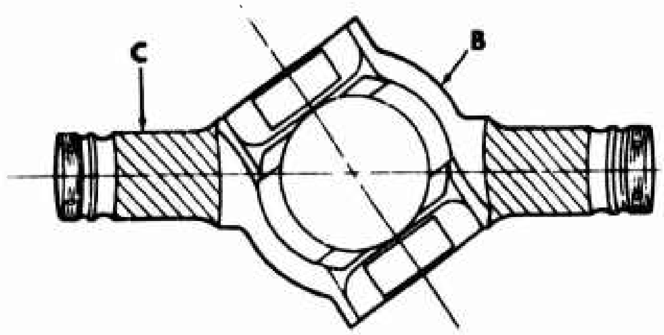


TAIL ROTOR GRIP P/N 204-011-728

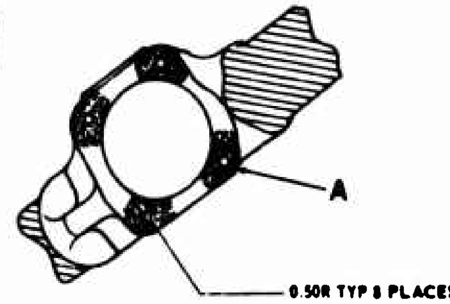
TYPE OF DAMAGE	AREA A	AREA B AS SHOWN MAXIMUM DEPTH	AREA C
NICKS, SCRATCHES SHARP DENTS	0.010	0.005	0.020
CORROSION	0.005	0.002	0.010
AREA OF FULL DEPTH REPAIR	0.10 INCH SQUARE	0.20 INCH SQUARE	0.30 INCH SQUARE
NUMBER OF REPAIR AREAS NON OVERLAPPING	TWO	TWO	TWO

1. DAMAGE TO THREADS LESS THAN ONE THIRD OF THE THREAD DEPTH MAY BE CLEANED UP TO EXISTING DEPTH FOR A TOTAL LENGTH OF ONE INCH.
2. COAT REPAIR AREAS ON ALUMINUM WITH BRUSH ALODINE OR ZINC CHROMATE PRIMER.
3. ALL EDGES MAY BE RADIUSED OR CHAMFERED LOCALLY TO DEPTH OF 0.030 INCH TO REMOVE NICKS OR DENTS.
4. ANY NICKS, SCRATCHES, AND SHARP DENTS NOT EXCEEDING THE MAXIMUM DAMAGE LIMITS, WILL BE DRESSED AND BLENDED INTO SURROUNDING AREAS.

Figure 14. Tail Rotor Hub Grip Damage Limits (Hub P/N 204-011-801), Models UH-1D/H.



YOKE ASSEMBLY P/N 204-011-722



TYPE OF DAMAGE	AREA A	AREA B	AREA C
NICKS, SCRATCHES, SHARP DENTS	0.005 inch Max. Depth	0.010 inch Max. Depth	Refer to Wear Limits Charts
CORROSION	0.002 inch Max. Depth	0.005 inch Max. Depth	

NOTES

1. Inspect damage inside roll pin holes with a five (5) to ten (10) power magnifying glass.

2. Local gouges 0.005 inch or less in depth at thread root inside roll pin hole may be cleaned up using a round jewelers file. Clean up area length is 20 percent of hole depth. Minor damage to the peak of the thread surrounding the pin holes requires no clean up unless during installation interference is encountered. Should interference occur, the thread may be dressed using an india-stone, providing peak thread damage is less than 30 percent of the thread depth. Damage to thread in excess of above limits is cause for scrapping yoke.

3. Gouges inside roll pin holes beyond thread root, do not affect useability of part.

4. Inside diameter of spindles in area of thrust unit is not a critical area. However, roll pin holes at this location and surrounding surfaces shall be cleaned up. Damage limit is maximum depth of 0.020 inch. Repair will be blended into surrounding area.

5. Scratches in trunnion housing bore may be polished out if less than 0.002 inch in depth.

6. Repair areas on cadmium plated surfaces, should be touched up with zinc chromate

* 7. All edges in Area B may be radiused or chamfered locally to a depth of 0.03 inch to remove nicks or dents.

* This note refers to Models UH-1D/H only.

Figure 15. Tail Rotor Hub Yoke Damage Limits (Hub P/N 204-011-801), Models UH-1D/H and AH-1G.

e. Inspect the following parts by magnetic particle method (M) or fluorescent penetrant method (F). Item numbers apply to Figure 12.

ITEM	NOMENCLATURE	CODE
1	Grip Assembly	F
14	Nut	M
16	Ring	F
22	Adapter Nut	M
24	Yoke	M
33	Trunnion	M

NOTE

All parts must be demagnetized after magnetic particle inspection.

f. Special magnetic particle inspection criteria have been established for the yoke (24, Figure 12) as follows:

(1) Each yoke shall be inspected by all of the following steps, using the wet continuous method. The true length of any indication shall be determined by the residual method of magnetization.

(2) Magnetize the part by positioning it so that the yoke arms contact the gauze contack heads of the machine, and pass 1400 amperes DC or 1100 ampers AC through the part for indications.

(3) Magnetize the part by placing it inside a coil so that the long axis of the part (yoke arms) is approximately 90 degrees to the direction of the current flow in the coil, and pass 1400 amperes DC or 1100 amperes AC through the part. Inspect the complete part for indications.

NOTE

Do not exceed 4200 amperes turns.

(4) Indications interpreted as cracks, seams, laps or shuts are cause for rejection.

(5) Indications of stringers or nonmetallic inclusions will be acceptable provided they do not exceed the following limits. Indications below 0.015625 inch in length are not considered rateable.

(a) Indications of defects parallel to the long axis of the yoke arms (plus or minus 15 degrees) are acceptable provided they do not exceed 0.500 inch in length and do not extend into the radius. The length of all rateable inclusions shall not exceed 1.0 inch total aggregate length.

(b) Indications of defects parallel to the long axis of the yoke arms (plus or minus 15 degrees) which extend into the radius are cause for rejection.

(c) Indications of defects in the yoke arms that are more than 15 degrees off the long axis, transverse or circumferential, are cause for rejection.

(d) Indications of defects on the outer surface of the yoke (excluding the yoke arms) are acceptable provided residual particle buildup does not indicate defects of the type mentioned in Paragraph 4.d.

(e) Indications which are caused by a sharp change in section are acceptable.

(f) Strong magnetic indications where considerable buildup of particles is present, indicating the defect has considerable depth and/or cross section, shall be cause for rejection,

regardless of length, size or direction.

(g) Indications of defects extending into, or in, threaded holes, threads or delta-hinge holes (1.875 inches diameter) are cause for rejection.

NOTE

Demagnetize part after completion of inspection and check to assure demagnetization.

5. Repair or Replacement (Figures 14 and 15)

NOTE

Refer to Table CXIV for tail rotor hub and hub components usability criteria.

a. Criteria

(1) Dimensional replacement limits apply to the physical item, "bare metal", prior to the application of any corrosion protection treatment, such as cadmium plating, dry-film lube, etc.

(2) Longitudinal scratches noted on the tail rotor yoke spindle which are not deeper than 0.002 inch, need not be completely removed; however, surface burrs should be removed using crocus cloth.

(3) Should the dry-film lube and/or cadmium plating require removal for any reason, it may be accomplished using abrasive cloth (Scotch Brite) saturated with methyl-ethyl-ketone.

(4) Whenever the cadmium plating or dry-film lube has been removed, it should be reapplied at the authorized echelon level in accordance with existing directives.

TABLE CXIV. TAIL ROTOR HUB AND HUB COMPONENTS, USABILITY CHART (HUB P/N 204-011-801-5 AND -9)

Nomenclature	Detail Part Numbers	No. of Items Per Hub For Dash Number *-5	No. of Items Per Hub For Dash Number **-9
Trunnion	204-010-785-1 or 204-011-737-1	1	
	204-011-737-1		1
Housing	204-010-786-1	2	2
Thrust-Washer	204-010-787-1	2	2
Thrust Cap	204-010-788-1	2	2
Shim	204-010-789-1	2	2
Yoke Assembly	204-011-722-1 or -5 204-011-722-5	1	 1
Grip	204-011-728-19 204-011-728-1 or -19	 2	2

* The -5 configuration incorporates uniform static stop points of contact for the tail rotor hub and blade assembly for left-side installation only.

** The -9 configuration incorporates uniform static stop points of contact for the tail rotor hub and blade assembly for either left-or right-side installation. This configuration was created to make one universal hub assembly for use on certain commercial helicopters.

b. Repair or replace, as applicable, any parts which are not within tolerances, or show evidence of failure, when inspected to the criteria outlined in Paragraph 4.

c. Replace all packings and seals on reassembly. Replace all unserviceable parts.

d. Dress splines and threads with a fine India oilstone if burrs or scratches are visible.

e. Repair tail rotor grip assembly (1, Figure 12) to the limits shown in Figures 13 and 14.

f. Repair tail rotor yoke (24, Figure 12) to the limits shown in Figures 13 and 15.

g. Refinish tail rotor grip assemblies (1, Figure 12). Apply one ocat epoxy polyimide and two coats acrylic lacquer on all external surfaces. Do not paint holes or bores.

6. Lubrication

a. Line grip assembly cavity with grease prior to reassembly.

b. At reassembly, lubricate all mating surfaces with lubricating oil.

c. Use corrosion preventive compound on mating threads of dissimilar metals.

7. Reassembly

a. If cork seals (34, Figure 12) were removed from yoke, apply shellac to new cork seals and install into yoke while wet.

b. Use seal bearing tool, T101407, to press bearing (32) into housing (31). Position trunnion (33) in place in yoke (24). Push housing, with bearing, into yoke and on trunnion.

c. Repeat Steps a and b to assemble parts on opposite end of trunnion.

d. Center trunnion (33) in yoke (24) as follows:

(1) Secure holding fixture, T101412, in a vise. Position yoke and trunnion onto tool with flat side of yoke down.

NOTE

Ensure that I.D. of yoke and trunnion are properly aligned and seated on tool.

(2) Install and tighten locking nut of tool onto assembly.

(3) Install thrust washer (28) and thrust cap (27) in place on each side of trunnion (33).

NOTE

Do not install shims (30) and packing (29) at this point of assembly.

(4) Temporarily install washers (26) and bolts (25). Tighten evenly and lightly.

(5) Use a feeler gage to measure gap between thrust cap (27) and mating surface of yoke (24) on one side of trunnion (33).

(6) Prepare a shim (30) to thickness determined in step (e), above.

(7) Remove 0.002 inch from shim to provide a total of 0.001 to 0.004 inch pinch fit on trunnion (33).

(8) Remove thrust cap (27), bolt (25) and washers (26) from measured side of trunnion (33).

(9) Install thrust washer (28), with groove outboard, packing (29) and previously prepared shim (30). Install thrust cap (27), bolts (25) and washers (26).

NOTE

Observe locations of lubrication fitting in thrust cap (27) at time of installation. Do not tighten bolts (25) at this point of installation.

(10) Prepare and install shim (30) for opposite side of trunnion (33) by same procedure outlined in Steps (3) through (9).

(11) Torque bolts (25) 20 to 25 inch-pounds, and lockwire bolt heads in pairs.

e. Determine for shimming, shim thickness for split cone clamp-up as follows (Figure 16):

(1) Identify spindle side, which is being evaluated for shim installation.

(2) Position radius ring onto the yoke spindle.

(3) Install thrust bearings (with thrust sides inboard), apex identification facing outboard, onto the yoke spindle.

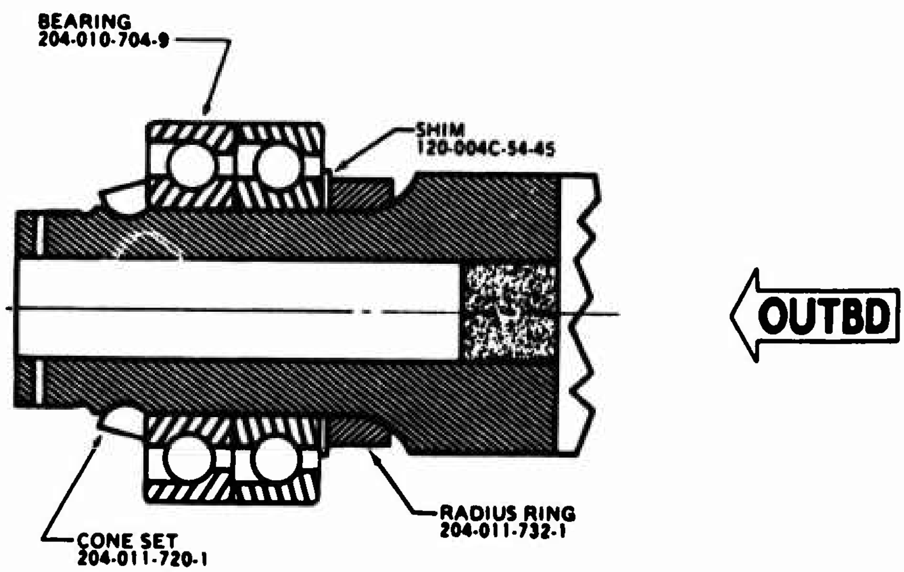


Figure 16. Shimming Tail Rotor Yoke.

CAUTION

To ensure proper stackup of bearings, "V" markings on O.D. of bearings must line up. As a further check on proper alignment prior to assembly on yoke, each outer race is marked "THRUST HERE" on inboard side of bearing outer race. Assemble on yoke spindle with "V" pointing outboard. The word "OUT' BD" should then appear on OUT' BD face of OUT' BD inner race.

(4) Place the split cone set into the groove provided on the yoke spindle, and retain in position with a small piece of tape.

(5) Apply finger pressure to the bearing set, in an outboard direction. Insert two feeler gages between the radius ring and the inboard bearing inner race 180 degrees apart. Record gap dimension obtained.

NOTE

In obtaining the above dimensional gap, tight feeler gage readings (heavy drag) are preferred.

(6) Take average of two readings obtained in Step (5). Add 0.002 to 0.004 inch to the dimension recorded. This figure will represent the shim thickness required.

(7) Remove the split cone set, bearing set, and radius ring and identify for reinstallation on that spindle side.

(8) Repeat Steps (1) through (7) on opposite yoke spindle.

f. Complete assembly of voke spindles as follows: (Figure 12)

CAUTION

Shims, bearings, and radius rings must be installed on same spindle as determined in Step e.

(1) Position radius ring (23) and adapter nut (22) on each spindle of yoke.

(2) Install seal (21) into spacer (20) and, with shim (19), slide into place on each spindle.

(3) Install bearings (18) with face marked "OUT' BD" positioned toward outboard side of yoke spindle.

(4) Install split cones (17), ring (16) and shims (15) on each side as required to permit installation of spring pins for locking nut.

NOTE

During installation of the split cones, a noticeable snap fit should be present, which will show that correct shim installation has been achieved.

Should either of the two following conditions be noted, incorrect shimming has been accomplished and Steps (1) through (7), under Paragraph (e), must be repeated:

1-Split cone set will not properly seat.

2-Radius ring will rotate during grip rotation.

(5) Install nut (14) and torque 100 to 125 inch-pounds. Install spring pins (13). Adjust shim (15), as necessary, and safety wire spring pins in place on each spindle.

NOTE

Prior to attempting to install spring pins, it is necessary that positive alignment be established to ensure damage-free assembly.

g. Assemble spring assembly (8) as follows:

(1) Stack washers (11) (Figure 12) (42 required consisting of 14 stacks of three washers per stack) and insert pin (10) with washers into case (12).

(2) Lock in place with cotter pin (9).

(3) Install shim (7) into open end of spring assembly; a maximum of 12 shims may be used for complete hub assembly. Install thrust plug (6) on top of shim (7); adjust thickness of shims as necessary to maintain 0.275 inch protrusion of thrust plug (6) above shoulder of spring assembly (8). (Figure 12)

h. Install adjusted spring assembly (Figure 17) into each end of yoke.

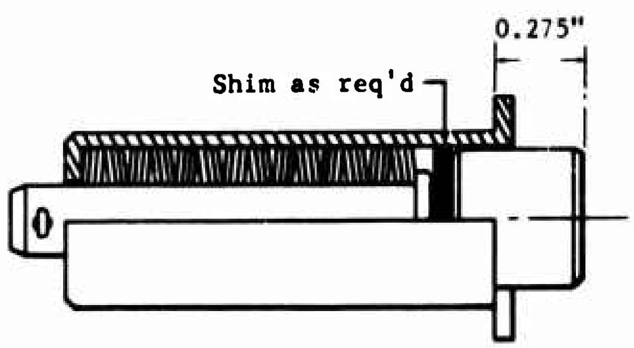


Figure 17. Shimming Tail Rotor Hub Spring Assembly (P/N 204-011-801).

i. Install shim (5) (Figure 12) on shoulder of sleeve in grip, which will rest against outer race of duplex bearings (18).

j. Install grip assembly (1) in place; align and screw adapter nut (22) into grip assembly.

NOTE

Line grip cavity completely with grease (MIL-G-25537) prior to assembly.

k. Torque adapter nut 500 to 600 inch-pounds. To overcome resistance of the assembly to seating properly, the adapter nut (22) must be torqued, backed off, and retorqued.

l. Position hub assembly on arbor portion of T101412 or T101457 tool, with flat side of hub down over flange of tool. Secure with wing nut. Install shim setting tool (gage assembly) in blade mounting holes. Check distance between pointer and shaft of tool on each side. Distance should be within 0.002 inch of each other.

m. If adjustment is necessary. Remove grip and adjust shim (5) as installed in step (i) and reassemble.

n. Install lockplates (4), washers (3) screw (2) on grip (1) shear flange into notch of nut (22). Lockwire in position.

o. Lubricate hub assembly at fittings provided on thrust caps (27) and grip assemblies (1) with grease.

NOTE

If thrust cap will not take grease, check for proper assembly.

Model UH-1C

A. NOTE: See UH-1D/H and add special part number 7HEL053, Balancing Part, to special tool list.

1. Removal

See UH-1D/H

2. Repair or Replacement

(Refer to Appendix I, pages 155 and 159 for inspection)

See UH-1D/H except:

a. NOTE appearing after Item (10) does not appear in UH-1C manual.

b. See UH-1D/H except:

(11) Size of inside diameter is not specified in the UH-1C manual.

c. Patch Repairs

See UH-1D/H except Item (10) reads:

(10) the patch may be held in place while curing with rubber bands made from an inner tube or other mechanical means. If epon 934 is used, cure at 75°F for a minimum of 5 days or at 180°F for 60 minutes. If metalset A4 is used, cure at 70° - 90° for 24 hours or at 145° - 155°F for 30 minutes.

3. Preparation of Blades for Shipment

See UH-1D/H

4. Installation

See UH-1D/H

B. Balancing Tail Rotor Assembly

See UH-1D/H except:

7. Add this note following this paragraph:

NOTE

The 204-011-801 hub uses half moon "beefed-up" center rings.

C. Tail Rotor Hub Assembly (P/N 204-011-801)

See UH-1D/H except:

1. Description

See UH-1D/H except:

a. Delete

2. Disassembly

See UH-D/H

3. Cleaning

See UH-1D/H

4. Inspection

See UH-1D/H except:

Refer to Figures 12 and 18 - 20.

a. NOTE following this paragraph does not appear in UH-1C manual.

e. Add the following to the NOTE following this step:

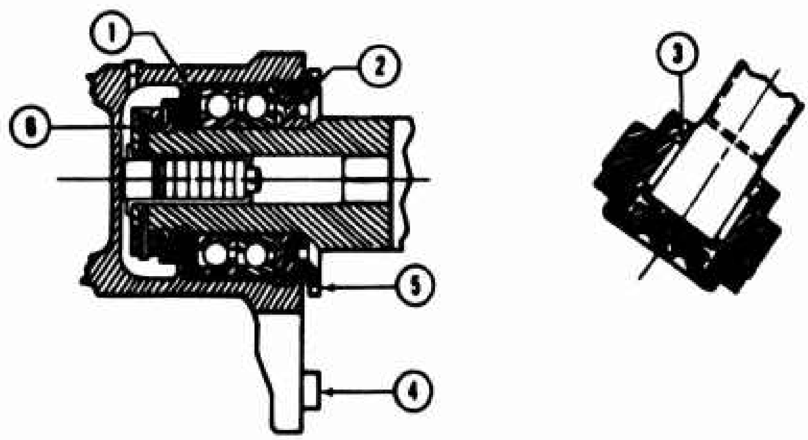
If magnetic indications are evident on the yoke assembly (24), only the yoke assembly and grip assembly require replacement.

5. Repair or Replacement

See UH-1D/H except:

a. Criteria

This paragraph and the NOTE preceding it do not appear in the UH-1C manual.



ITEM	NOMENCLATURE		MIN.	MAX.	REPLACE
1	Grip Liner	ID	2.4410	2.4415	2.4425
2	Yoke, Bearing Seat	OD	1.3771	1.3780	1.3763
3	Trunnion Spindle	OD	1.1246	1.1250	1.1230
4	Bushing, Pitch Link	ID	0.3120	0.3125	0.3155
			TORQUE		
5	Nut	IN. LB	500	600	
6	Nut	IN. LB	100	125	

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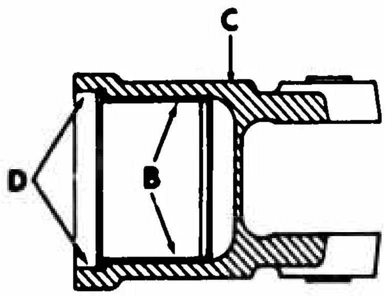
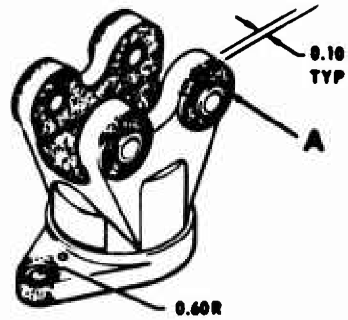
Figure 18. Tail Rotor Hub Limits (P/N 204-011-801-5), Model UH-1C.



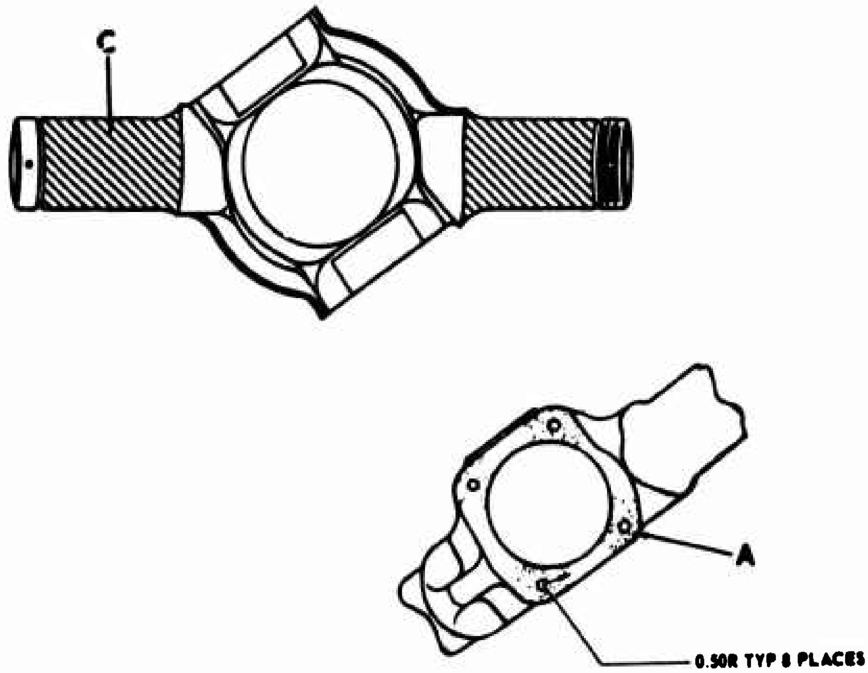


TYPE OF DAMAGE	AREA A	AREA B	AREA C
NICKS, SCRATCHES, SHARP DENTS	0.005 inch Max. Depth	0.005 inch Max. Depth	0.020 inch Max. Depth
CORROSION	0.002 inch Max. Depth	0.002 inch Max. Depth	0.010 inch Max. Depth

NOTES

1. ANY DAMAGE TO THREADS D IS CAUSE FOR SCRAPPING THE PART.
2. SCRATCHES IN BUSHING BORES MAY BE POLISHED OUT IF LESS THAN 0.002 INCH IN DEPTH.
3. MAXIMUM REPAIR AREA OF AREA A IS 20% WITHIN 0.6 INCH OF BOLT HOLE CENTER LINE.
4. MAXIMUM REPAIR AREA OF AREA B NOT TO EXCEED 5% OF TOTAL SURFACE. MAXIMUM SINGLE REPAIR AREA SHOULD NOT EXCEED 0.10 SQUARE INCH.
5. REPAIR AREAS ON ANODIZED SURFACES SHOULD BE RECOATED BY BRUSHING WITH ANODINE SOLUTION.
6. MAXIMUM SINGLE REPAIR AREA OF AREA C SHOULD NOT EXCEED 0.25 SQUARE INCH AND 0.60 INCH IN WIDTH.

Figure 19. Tail Rotor Hub Grip Damage Limits (P/N 204-011-801-5 and 204-011-701), Model UH-1C.



TYPE OF DAMAGE	AREA A	AREA B	AREA C
NICKS, SCRATCHES, SHARP DENTS	0.005 inch Max. Depth	0.010 inch Max. Depth	Refer to Wear Limits Charts
CORROSION	0.002 inch Max. Depth	0.005 inch Max. Depth	

NOTES

1. ANY DAMAGE TO SPINDLE THREADS IS CAUSE FOR SCRAPPING THE YOKE.
2. SCRATCHES IN TRUNNION HOUSING BORE MAY BE POLISHED OUT IF LESS THAN 0.002 INCH IN DEPTH.
3. REPAIR AREAS ON CADMIUM PLATED SURFACES SHOULD BE RECOATED BY BRUSHING WITH CADMIUM PLATING SOLUTION.

Figure 20. Tail Rotor Hub Yoke Damage Limits (P/N 204-011-801-5), Model UH-1C.

e. Refer to Figures 18 - 20.

f. Refer to Figures 19 and 20.

g. Replace with the following:

Refinish tail rotor grips. Apply two coats of catalyzed epoxy paint to the exterior, fit bushings, and interior tangs of the grips. After completion of 1 hour air-dry, the applied coating will be cured for 10 minutes at 300°F.

6. Lubrication

See UH-1D/H

7. Reassembly

See UH-1D/H except:

f. (2) Add the following:

NOTE

Shim (19) as required to maintain a 0.002 to 0.004 inch pinch fit with split cone set (17) contacting the outboard surface of the radius on yoke spindle.

(3) Add the following:

CAUTION

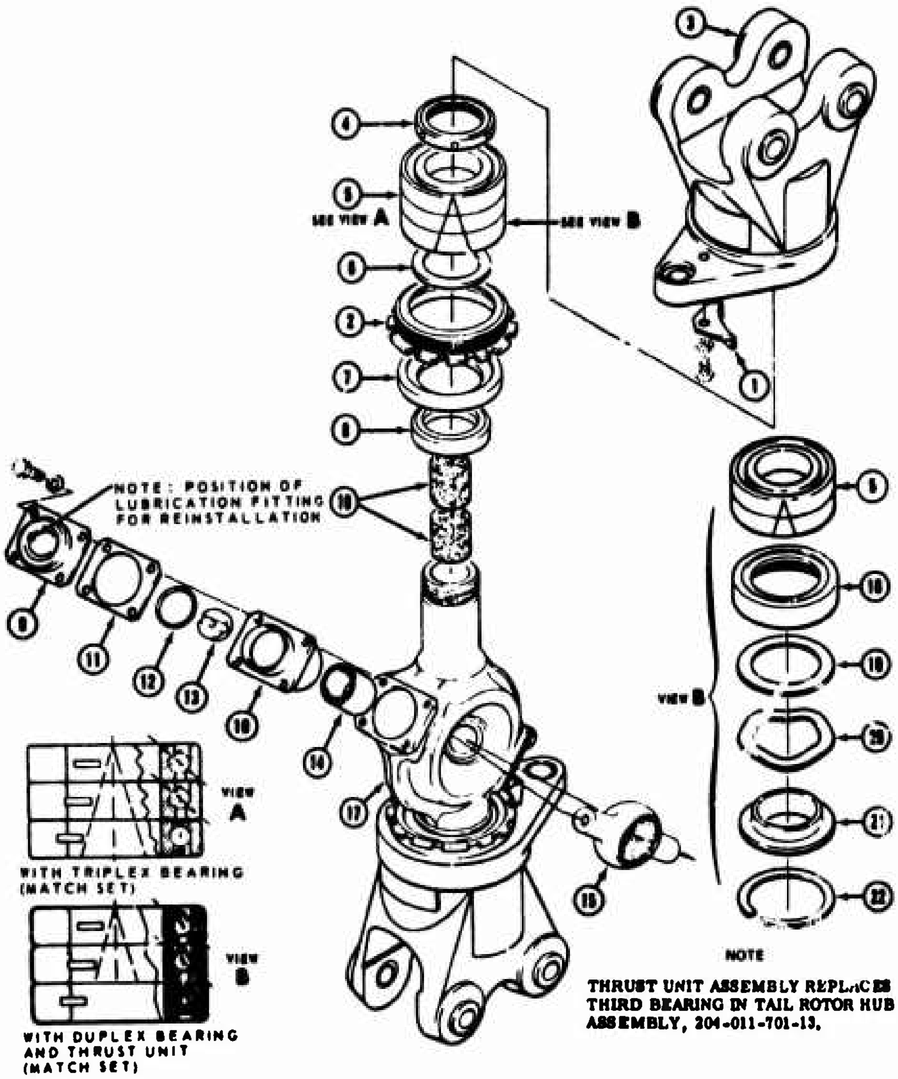
To insure proper stack-up of bearings, both inboard and outboard faces of each bearing are marked. Install each bearing onto spindle of yoke separately, noting "inboard" and "outboard" position.

(4) Delete the note following this paragraph.

D. Tail Rotor Hub (P/N 204-011-701)

1. Disassembly (see Figure 21)

a. Remove tail rotor hub and blade assembly. (Refer to Appendix I, page 155)



1. Lockplates
2. Blade Grip Retainer Nuts
3. Grip Assemblies
4. Bearing Retainer Nuts
5. Bearing Set
6. Shims
7. Seals
8. Radius Rings
9. Thrust Cap Assemblies
10. Trunnion Bearing Housings
11. Trunnion Shims
12. Preformed Packing
13. Thrust Washers
14. Bearings
15. Trunnion
16. Cork Plugs
17. Yoke Assembly
18. Outer Ring - Thrust Unit
19. Thrust Washer - Thrust Unit
20. Wave Washer - Thrust Unit
21. Inner Ring - Thrust Unit
22. Retaining Ring - Thrust Unit

Figure 21. Tail Rotor Hub Assembly (P/N 204-011-701), Model UH-1C.

b. Cut lockwire and remove screws and washers attaching lockplates (1) to grip assemblies. Remove lockplates. Back off blade grip retainer nuts (2) and remove grip assemblies (3). Remove pins and bearing retainer nuts (4) from yoke assembly spindles. Remove bearing sets (5) and shims (6).

CAUTION

Remove roll pins from bearing retainer nuts by driving pins from the inside of the spindle area in an outboard direction.

CAUTION

Keep bearing sets (5) and shims (6) together in sets when and as removed.

NOTE

Tail rotor hub assembly, 204-011-701-13, has a thrust unit assembly with duplex bearings instead of triplex bearings as indicated on Figure 21. Disassembly procedure is the same.

c. Remove blade grip retainer nuts (2, Figure 21) and use seal and bearing tool T101407 to remove seals (7) from retainer nuts (2). Remove radius rings (8).

d. Cut lockwire, remove bolts and washers attaching thrust cap assemblies (9) to trunnion bearing housing (10), and remove cap assemblies. Remove trunnion shims (11), O-rings (12), and thrust washers (13).

e. Remove bearings (14) from trunnion bearing housings (10) with seal and bearing tool, T101407. Remove trunnion (15) and cork plugs (16) from yoke assembly (17).

2. Cleaning

See Paragraph C.3.

3. Inspection

a. Visually inspect all parts for damage, excessive wear, or corrosion. Check bearings for smooth operation and general condition. Inspect splines in trunnion for chipped or worn teeth. Inspect component of thrust unit assembly.

b. Inspect the following parts by magnetic particle method (Code M) or fluroescent penetrant method (Code F). Item numbers are applicable to Figure 21.

ITEM	NOMENCLATURE	CODE
2	Blade Grip Retainer Nut	M
3	Grip Assembly	F
4	Bearing Retainer Nut	M
15	Trunnion	M
17	Yoke Assembly	M
	Grip Assembly Inner Liner	M

NOTE

If magnetic indications are evident on yoke assembly (17), only the yoke assembly and grip assembly require replacement.

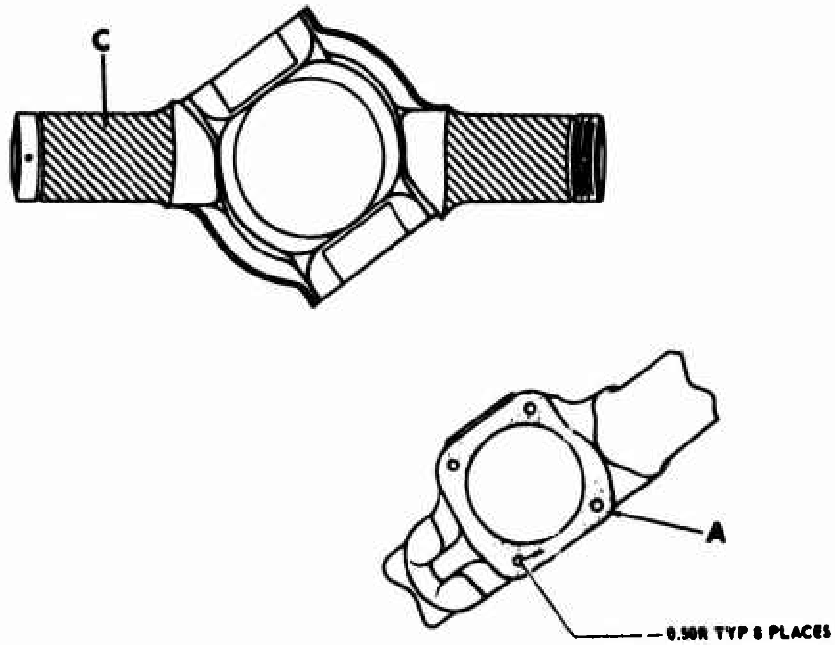
c. Inspect parts for mechanical and corrosion damage. (See Figures 19, 20, and 22)

d. Inspect parts dimensionally. (see Limits Chart, Figure 23)

4. Repair or Replacement

See Paragraph C.5(c) and (e).

Reword Paragraph C.5(d) to read:



TYPE OF DAMAGE	AREA A	AREA B	AREA C
NICKS, SCRATCHES, SHARP DENTS	0.005 inch Max. Depth	0.010 inch Max. Depth	Refer to Wear Limits Charts
CORROSION	0.002 inch Max. Depth	0.005 inch Max. Depth	

NOTE

1. Damage caused by removing roll pins may be repaired using the following limits: other damage is cause for rejection.

   a. Roll pins used to secure the tail rotor thrust bearing retaining nut P/N 204-010-711-3 should be removed by driving the pins from the inside of the spindle area in an outboard direction. Due to the design of the nut, it is possible to drive sufficient metal from the nut downward on to the threaded portion of the spindle which will prevent damage-free removal of the nut should the above method not be adhered to.

   b. Minor damage to the peak of the thread surrounding the pin holes requires no cleanup unless during nut installation interference is encountered. Should this occur, the thread may be dressed using an India-stone, providing peak thread damage is less than 30% of the thread depth.

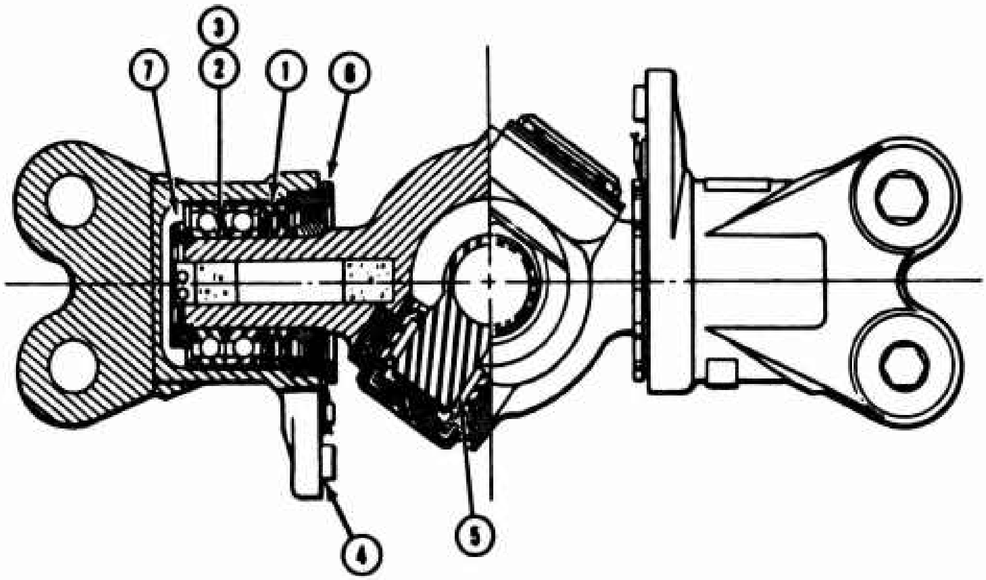
   c. Should local gouges be detected at the thread root itself whthin the hole provided for the roll pin, they may be cleaned up to a maximum depth of .005 inch using a round swiss pattern (jewelers) file.

   d. The depth of nicks, scratches or gouges is limited to a maximum of .020 inch on the cylindrical portion of the inside diameter of the spindle outboard of the cork. It will be necessary to blend all repairs using a generous radii into the surrounding area.

   e. Prior to attempting installation of the roll pins, it is mandatory that positive alignment be established to insure damage free assembly.

2. Scratches in trunnion housing bore may be polished out if less than 0.002 inch in depth.

Figure 22. Tail Rotor Hub Yoke Damage Limits (P/N 204-011-701), Model UH-1C.



ITEM	NOMENCLATURE		MIN.	MAX.	REPLACE
1	Blade Grip Liner	ID	2.4410	2.4415	2.4423
2	Bearing, Thrust (2 Required) *	OD	2.4404	2.4409	2.4395
		ID	1.3775	1.3780	1.3790
3	Yoke Thrust Bearing Seat	OD	1.3773	1.3778	1.3750
4	Link Attachment Hole	ID	0.2495	0.2500	0.2525
5	Trunnion Spindle		1.1246	1.1250	1.1230
			TORQUE		
6	Nut	IN./LB	300	600	
7	Nut	IN./LB	300	800	

* Three (3) required for the -13 hub assembly

Figure 23. Tail Rotor Hub Limits (P/N 204-011-701), Model UH-1C.

d. Remove burrs and sharp edges on thrust unit inner ring caused by spring tension. Remove minor nicks and scratches which are not deeper than 0.005 inch using a fine India oilstone.

5. Lubrication

See Paragraph C.6.

6. Reassembly

Refer to Figure 21.

NOTE

Prior to performing reassembly procedures, thoroughly degrease bearing retainer nut (4) and exposed threads of yoke assembly (17) spindle. Apply coating of primer to threaded surfaces of retainer nut and spindle.

a. Install cork plugs (16) in yoke assembly (17) spindles and secure with shellac. Use seal and bearing tool, T101407, to press bearings (14) into trunnion bearing housings (10). Position trunnion (15) in place of yoke assembly (17), and insert bearing and housing assemblies into yoke assembly (17) and on trunnion (15).

CAUTION

Press bearing (14) into housing (10) so that seal will be inboard when bearing and housing are assembled on trunnion (15).

b. Position trunnion (15) on threaded end of grip spacing tool, T101412, with flat side of hub down in place on flange of tool, and tighten nut against yoke assembly (17). Install thrust washer (13) with grease fitting groove against thrust cap assembly (9). Position thrust cap assembly (9) on trunnion bearing housing (10). Hold cap assembly (9) and housing (10) together

and move inboard until cap assembly bottoms against thrust washer (13). With cap assembly and housing held together, measure gap between cap assembly (9) and housing (10). Shim as required to provide 0.000 to minus 0.002 inch pinch on trunnion.

c. Repeat step b on opposite side.

d. Install preformed packing (12) in cap assembly (9) with four bolts, with thin washers under bolt heads. Assure correct positioning of lubrication fitting (Refer to Figure 21)

e. Repeat procedure on opposite trunnion.

f. Check for freedom of turning of yoke and trunnion on the tool. Trunnion should now be centered 0.001 to 0.004 inch pinch fit.

NOTE

If trunnion is not centered, the yoke will bind on flange of tool (T101412). This condition will occur if the pinch on one side is not approximately equal to that on the other. If binding occurs, repeat steps b thru f above.

g. Lockwire four bolts in pairs when binding is eliminated.

h. Use seal and bearing tool, T101407, to press seals (7) into blade grip retainer nut (2) with metal side of seal against shoulder in nut. Install radius ring (8) on yoke assembly (17) spindle, with radius of ring mated to radius of spindle. Position retainer nut (2) and seal (7) assembly over radius ring (8). Install shim (6) next to radius ring (8). Install bearing set (5) on spindle with apex marks aligned. (See View A, Figure 21)

NOTE

When necessary and conditions warrant, bearing assemblies P/N 204-010-704-1 (triplex) or P/N 204-010-709-1 (duplex) need not be installed in serialized sets. Serviceable, used bearings may be mix-matched, providing apex installation marks are maintained. (See Figure 24.) The preloaded bearing (bearing most inboard) must be retained in its original position with the apex pointing outboard. New bearing will remain in matched sets and will be installed in accordance with existing technical manuals.

i. Apply sealing compound to threaded portions of retainer nut (4) and yoke assembly spindle. Install retainer nut on yoke assembly spindle next to bearing set (5), with thin side of retainer nut outboard.

NOTE

To assure proper thread engagement of nut (2) to threads of yoke (17), use a minimum shim (6) thickness to allow nut to set flush with, or below, end of yoke.

j. Use a suitable spanner wrench and tighten nut to a torque of 300 to 800 inch-pounds. Align holes and install two pins through holes at positions 180 degrees apart. Allow Loctite to cure 45 minutes before installing grip and blade assemblies.

NOTE

The application of Loctite does not apply to tail rotor P/N 204-011-701-19, as roll pins are installed and not cotter pins.

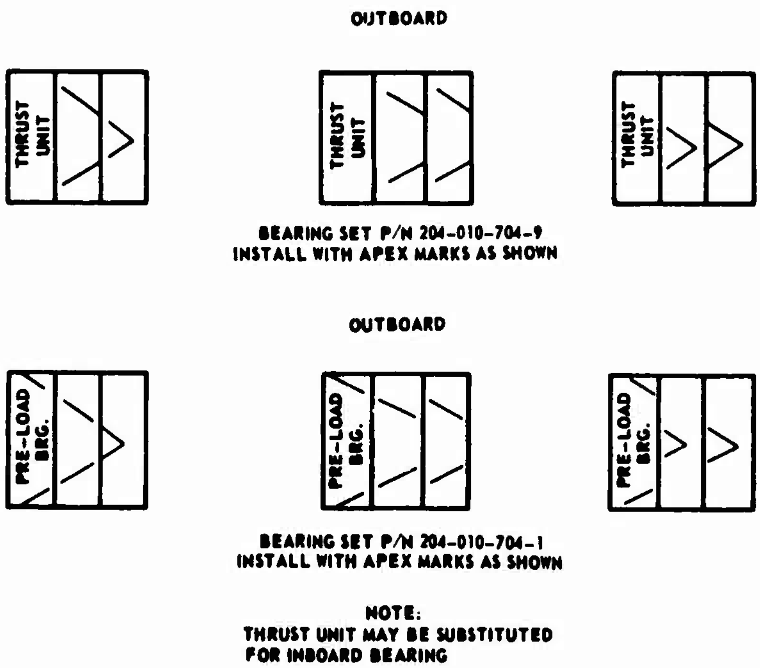


Figure 24. Tail Rotor Hub Bearings - Apex Alignment Mark (P/N 204-011-701), Model UH-1C.

k. Repeat steps f, g, and h on opposite side.

l. Install grip assemblies (3) over bearing sets (5). Align and screw blade retainer nuts (2) into grip assemblies. Torque nuts 300 to 600 inch-pounds.

m. Check grips for equal spacing, using T101412 tool set.

   (1) Secure shaft of tool upright in a vise.

   (2) Position hub trunnion on shaft with flat side of hub down. Install wing nut on shaft.

   (3) Install gage assembly of tool on either grip with studs in blade mounting holes. Use a feeler gage to measure gap between gage rod and tool shaft.

   (4) Move gage to opposite grip and repeat measurement.

   (5) Compare measurements, to be equal within 0.004 inch. If not within tolerance, disassemble the grip with greatest dimension and peel shim (6, Figure 21) as required. After reassembly, repeat gaging procedure.

   (6) When check is satisfactory, remove tools.

n. Install new lockplates (1) on grips in position shown on Figure 21. Install attaching washers and screws. Using suitable punch, bend lockplate in, engaging retainer nut (2). Lockwire attaching screws.

Model AH-1G

A. NOTE: See UH-1D/H and add to special tool list, part number T101361, external spline assembly wrench.

1. Removal

See UH-1D/H except:

a. Refer to Appendix I, page 156

2. Repair or Replacement

See UH-1D/H except:

a. The NOTE following Paragraph (10) does not appear in the AH-1G manual.

b. Replace Paragraph (10) with the following:

(10) Temporarily secure patch in place using rubber bands cut from an inner tube or by other mechanical means. Cure at 70° to 90°F for 24 hours or 140° to 155°F for 30 minutes.

3. See UH-1D/H and add the following to the WARNING following Paragraph e:

Attach a properly filled out DD form 1577-2 (Unserviceable/Reparable) Tag to blade.

4. See UH-1D/H except:

NOTE preceding Paragraph b does not appear in AH-1G manual.

B. Balancing Tail Rotor Assembly

See UH-1D/H except:

Delete NOTE following Paragraph 14. Replace Paragraph 15 with the following:

15. Final balance tail rotor assembly within 20 inch-grams, spanwise and chordwise as follows:

NOTE

Do not remove or rework blade assembly weights.

a. Determine light side of tail rotor assembly spanwise and chordwise.

b. Balance hub and blade assembly by using a combination of washers (AN960-716, 204-011-708-1, and -3) added to blade bolts on the light side of assembly under nuts.

c. Do not use over six washers of any combination on -800 assemblies.

d. Select proper-length blade bolt from acceptable lengths (AN177-35A through AN177-40A), to accommodate washers.

NOTE

Blade bolts may be assembled with heads either inboard or outboard, but all four bolts are to be installed the same.

e. Assemble balance washers with heaviest washer adjacent to blade grip.

f. Torque nuts on blade bolts to 270 to 300 inch-pounds when hub and blade assembly is in balance.

C. Tail Rotor Hub Assembly (P/N 204-011-801-3)

See UH-1D/H except:

Refer to Figure 25

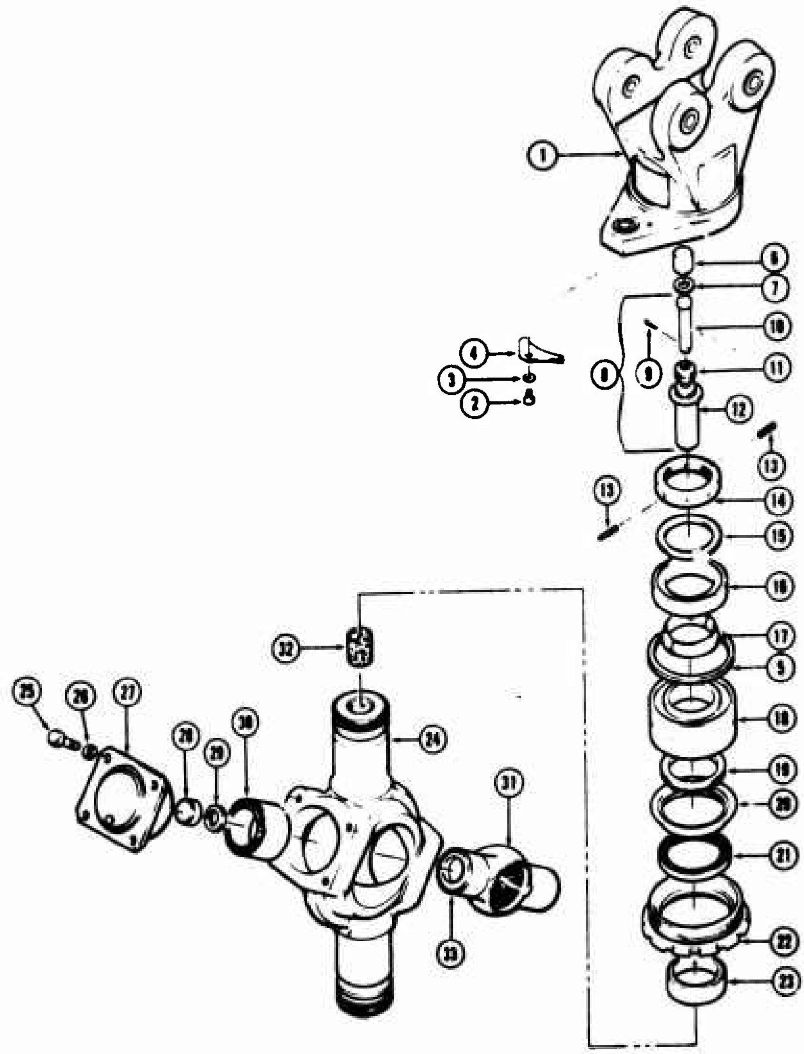
1. Description

Delete Paragraphs a and b.

2. Disassembly

a. Replace with the following:

Secure hub assembly in vise using T101412 or T101457 as a holding fixture with flat side of yoke down.



1. Grip Assembly
2. Bolt
3. Washer
4. Lockplate
5. Shim
6. Plug
7. Shim
8. Spring Assembly
9. Cotter Pin
10. Pin
11. Washers
12. Housing
13. Spring Pin
14. Nut
15. Shim
16. Ring
17. Split Cone
18. Bearing Set
19. Shim
20. Spacer
21. Seal
22. Nut
23. Radius Ring
24. Yoke
25. Bolt
26. Washer
27. Housing
28. Thrust Plug
29. Shim
30. Bearing
31. Trunnion
32. Cork
33. Bearing Inner Race

Figure 25. Tail Rotor Hub Assembly (P/N 204-011-801), Model AH-1G.

g. NOTE

Delete the phrase "for reassembly in the same position."

m. Replace with the following:

Cut lockwire and remove four bolts (25), washers (26), and housing (27).

n. Replace with the following:

Remove thrust plug (28) on shims (29). Index shims for installation on same spindle from which removed.

o. Replace with the following:

Remove housing (27) and extract bearing (30) from housing using a suitable bearing puller.

3. Cleaning

See UH-1D/H

4. Inspection

See UH-1D/H except:

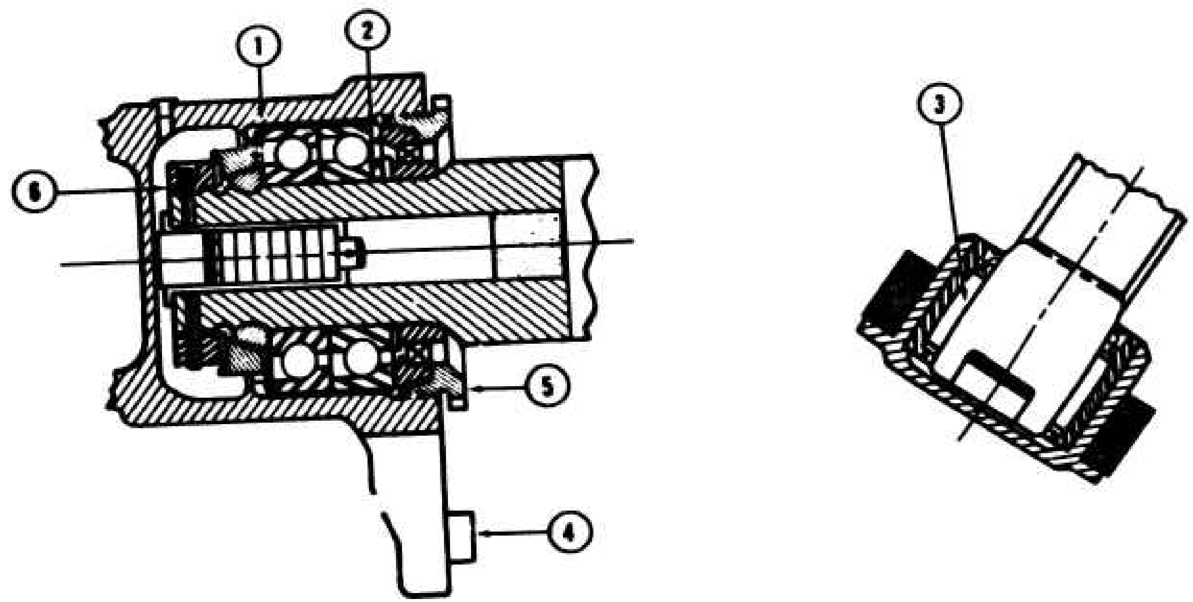
a. Refer to Figures 25 - 27 and 15.

b. Refer to Figure 25.

c. Refer to Figure 26.

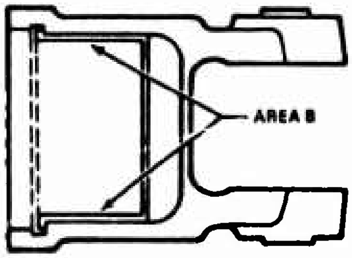
d. Replace Paragraph e with the following:

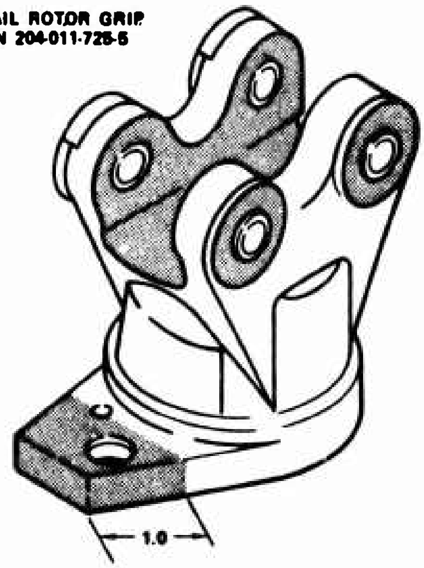
Inspect the following parts by Magnetic Particle (Code M) method MIL-I-6868 or Fluorescent Penetrant (Code F) MIL-I-6866 as required. Remove inner race (33, Figure 25) from trunnion (31) for inspection. Install race on trunnion after inspection, if both the race and trunnion are acceptable.



ITEM	NOMENCLATURE		MIN.	MAX.	REPLACE
1	Grip Liner	ID	2.4410	2.4415	2.4425
2	Yoke, Bearing Seat	OD	1.3771	1.3780	1.3750
3	Trunnion Spindle	OD	1.1246	1.1250	1.1230
4	Bushing, Pitch Link	ID	0.3120	0.3125	0.3155
			TORQUE		
5	Nut	In./Lb	500	600	
6	Nut	In./Lb	100	125	

Figure 26. Tail Rotor Hub Limits (P/N 204-011-801), Model AH-1G.





TYPE OF DAMAGE	AREA A	AREA B AS SHOWN MAXIMUM DEPTH	AREA C
NICKS, SCRATCHES SHARP DENTS	0.010	0.005	0.020
CORROSION	0.005	0.002	0.010
AREA OF FULL DEPTH REPAIR	0.10 INCH SQUARE	0.20 INCH SQUARE	0.30 INCH SQUARE
NUMBER OF REPAIR AREAS NON OVERLAPPING	TWO	TWO	TWO

Notes

1. Damage to threads less than one third of the thread depth may be cleaned up to existing depth for a total length of one inch.
2. Coat repair areas on aluminum with brush alodine or zinc chromate primer.
3. All edges may be radiused or chamfered locally to depth of 0.030 inch to remove nicks or dents.

Figure 27. Tail Rotor Hub Grip Limits (P/N 204-011-801), Model AH-1G.

ITEM	NOMENCLATURE	CODE
1	Grip Assembly	F
14	Nut	M
16	Ring	F
22	Nut	M
24	Yoke	M
31	Trunnion	M

e. Refer to Figure 30.

5. Repair or Replacement

See UH-1D/H except:

Refer to Figures 27 and 15.

a. Delete this paragraph.

e. Refer to Figures 25, 26, and 31 respectively instead of those indicated in UH-1D/H section.

f. Refer to Figures 25, 26, and 15 respectively instead of those indicated in UH-1D/H section.

g. Delete

6. Lubrication

See UH-1D/H except:

b. Delete

7. Reassembly

See UH-1D/H except:

Refer to Figure 29 and replace index numbers with those indicated below. Where more than one number appears in one paragraph, they are listed in the order in which they are to be used.

a. Replace index number with 32.

b. Replace index numbers with 30, 27, 31, 24. Also, add the following:

Use enough shim to produce a gap between housing and yoke. Ensure that all parts are seated.

c. Add the following to this paragraph:

Install bolts (25) and washers (26).

d. Replace Paragraphs (3) through (11) with the following:

(3) Using a feeler gage, measure the gap between housing (27) and mating surface of yoke (24), and record.

(4) Remove bolt (25), washers (26), housing (27), plug (28) and shims (29) from measured side of trunnion. Peel shim (29) to close gap to 0.000 to 0.002 inch. The total amount of shim removed may not be greater than the width of the gap measured in step c above.

(5) Install prepared shim (29), plug (28), housing (27), bolts (25), and washers (26) on trunnion.

(6) Prepare and install shim for opposite side of trunnion following steps (3) through (5) to provide a tool of 0.001 to 0.004 inch pinch fit on trunnion.

(7) Torque bolts (25) 20 to 25 inch-pounds, and lockwire bolt heads in pairs.

e. Delete figure reference.

(3) Delete CAUTION following this paragraph.

Add the following paragraph:

(9) Reassemble the tail rotor hub assembly in accordance with existing instructions contained in the appropriate maintenance manual.

f. Change figure reference to Figure 25. Delete CAUTION preceding Paragraph (1). Delete NOTE following this paragraph.

g. Change figure reference to:

(3) Figure 25

i. Change figure reference to:

Figure 25

o. Delete NOTE following this paragraph.

APPENDIX VI

MTBF AND MTBR PREDICTIONS FROM MIRF REPORT DATA USING WEIBULL DISTRIBUTION ANALYSIS TECHNIQUES

1.0 THE ANALYSIS OBJECTIVE

Section 6 and Appendix II present the results of analyses of tail rotor system component data obtained from Major Item Removal Frequency (MIRF) reports. The analysis results include MTR/MTBR and MTBF predictions. In addition, the analysis includes an estimate of the component MTBR that would be achieved if all the components removed prior to time change for nonfailure-caused removal reasons were reinstalled and operated until failure or time change required their removal. This MTBR estimate is based on the consideration that the component's failure rate is exponential.

The objective of this appendix is to show another analysis approach that may be used to predict the component MTBF and MTBR values from the MIRF reports if the component failure rate is Weibull rather than the classical exponential. The effect on the estimated MTBR value of off-aircraft repair (not including overhaul) to a percentage of the failed components is also examined using equations developed during this program.

2.0 THE ANALYSIS APPROACH

This analysis procedure takes the MIRF data, plots it on Weibull graph paper, determines the characteristics of the distributions, predicts comparable exponential distributions, and identifies MTBF values from which MTBR values can be estimated.

2.1 The Weibull Equations

The Weibull reliability equation used in this analysis is

$$R = e^{-\left(\frac{t}{\theta}\right)^{\beta}} \tag{47}$$

where R = the reliability at time t

θ = the characteristic life of a Weibull distribution with a shape parameter β

The distribution frequently called the exponential distribution is a special case of the Weibull distribution where β is equal to one.

The characteristic life θ is the time t when the fraction that failed is equal to $1 - e^{-1}$ or .632. This is true regardless of the shape parameter. In an exponential distribution the characteristic life is also the mean value. The mean value of the Weibull distribution is determined from the following equations:

$$\mu = \theta \; \Gamma(1 + 1/\beta) \tag{49}$$

and

$$F(\mu) = 1 - \exp\left[-(\mu/\theta)^{\beta}\right] = 1 - \exp\left\{-\left[\Gamma(1 + 1/\beta)\right]^{\beta}\right\} \tag{50}$$

where μ = the mean of the Weibull distribution

$F(\mu)$ = the fraction failed at $t = \mu$

$\Gamma(x) = \int_0^{\infty} u^{x-1} e^{-u} du$ is the gamma function

A curve relating the fraction failed $F(\mu)$ at the mean to the shape parameter β over the β range observed in the analyses is shown in Figure 28.

2.2 Weibull Graph Paper

Figure 29 is a form of Weibull graph paper developed by Mr. James R. King of a company called Technical and Engineering Aids for Management (TEAM) of Tamworth, New Hampshire. It is similar to other Weibull graph paper except for some features. The paper has a log scale along the horizontal time axis and a Weibull probability scale along the vertical axis. Points of accumulative percentage of failure are plotted against elapsed time. If the points approximate a straight line and a line is so drawn through them, this represents the Weibull distribution of the plotted points. The intersection of the line and 62.3 percent failures will locate the time that is equivalent to the characteristic life θ. A line parallel to the distribution passing through the origin of the small beta estimator will identify the β parameter of the distribution. Other characteristics of the paper are described in Reference 30.

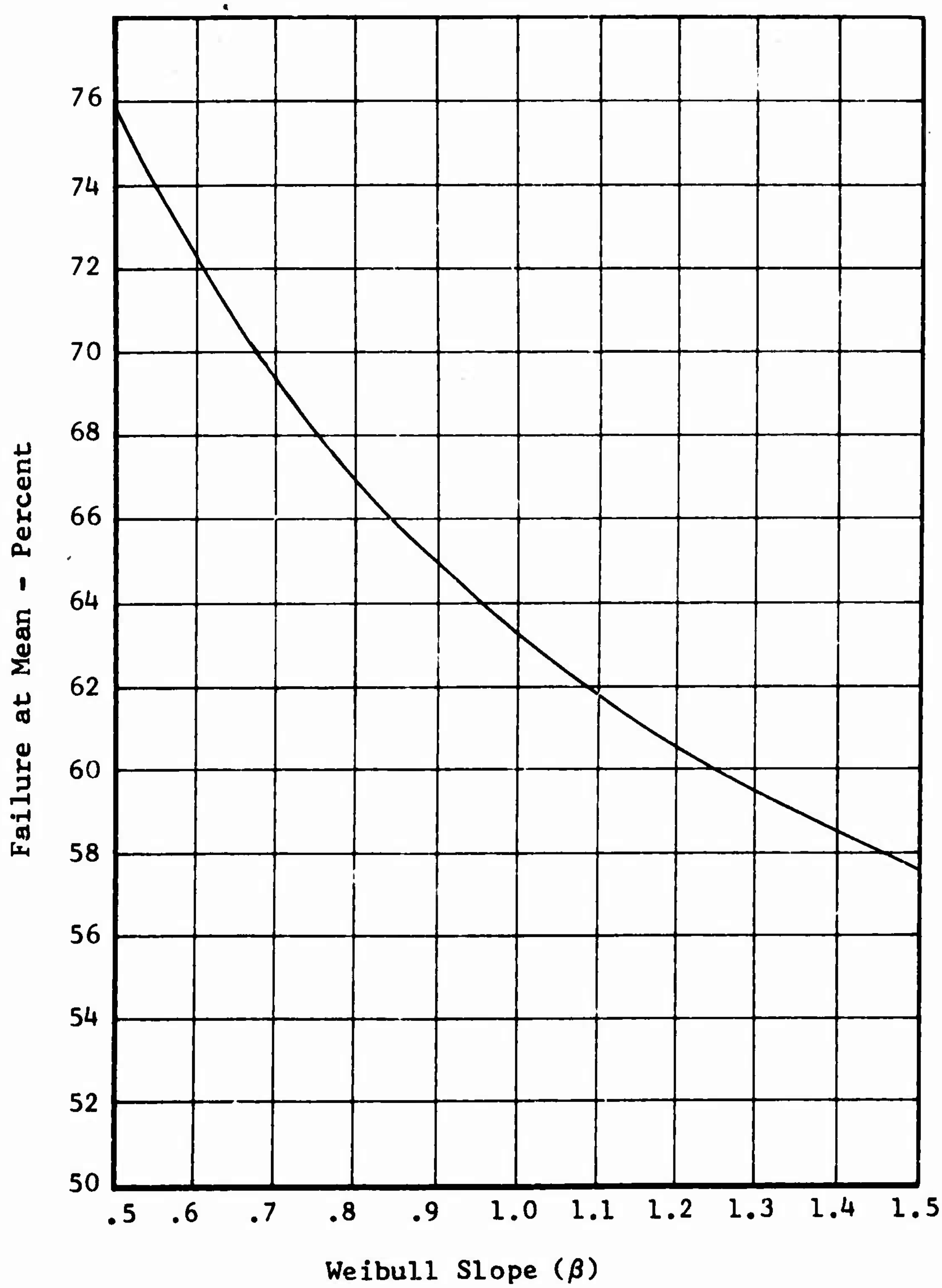


Figure 28. Plot To Determine the Location of the Weibull Mean from β.

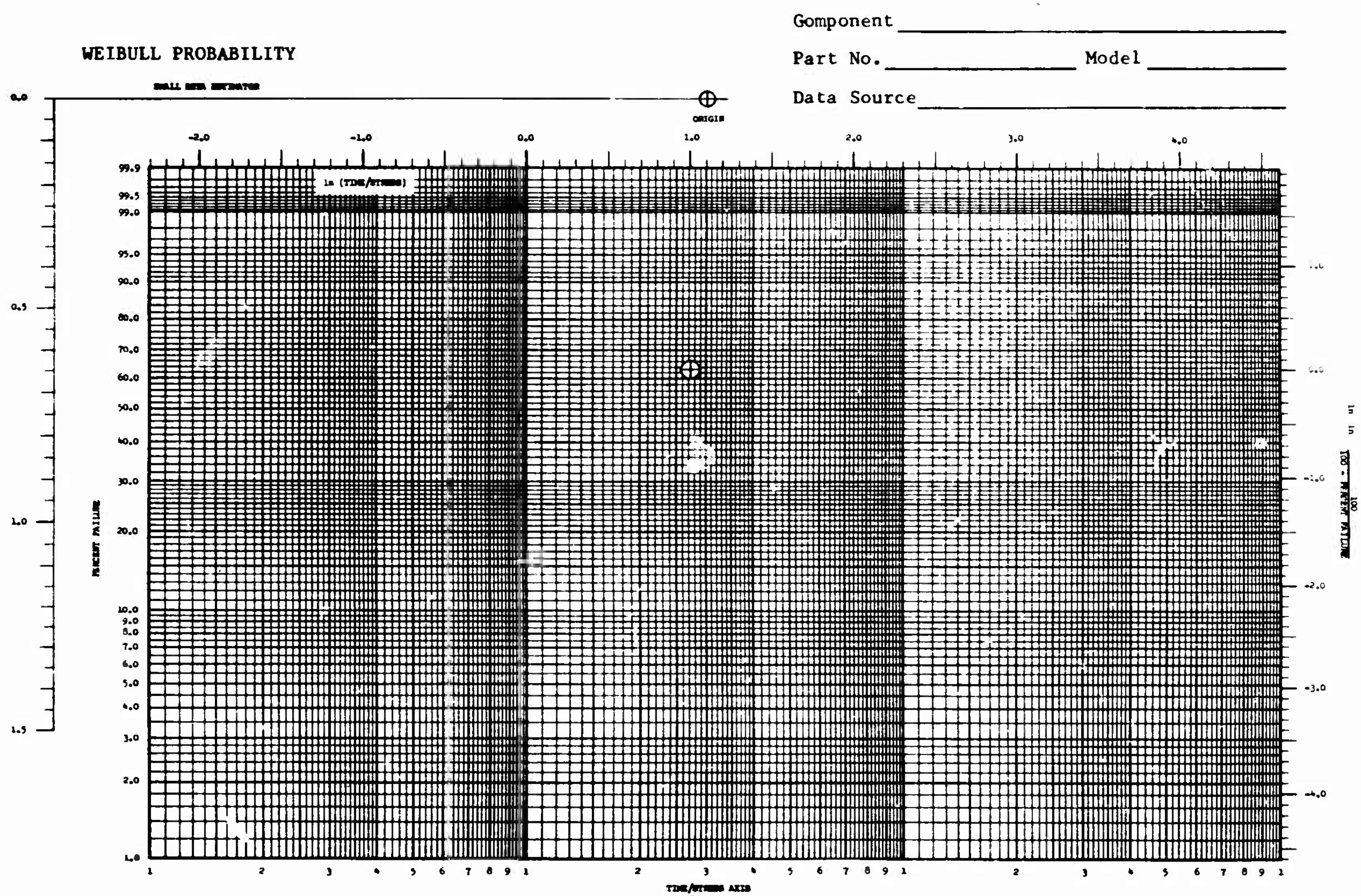


Figure 29. An Example of Weibull Graph Paper.

2.3 Characteristics of the Data

The Major Item Removal Frequency (MIRF) reports are prepared by the Reliability and Maintainability Management Improvement Techniques (RAMMIT) System of the Systems Performance Assessment Division, Product Assurance Directorate, Army Aviation Systems Command, St. Louis, Missouri. The MIRF reports contain a breakdown by failure code of the initial removals per 100-hour flight-hour interval for those components which are included in the DA Form 2410 reporting system. This information is tabulated for each specific Federal stock number/part numbered component and is reported by aircraft model. Listings for those components with no prior overhauls and those with one prior overhaul are included. The total number of removals as well as the percentage of total removals is shown for each 100-hour flight-hour interval. The report is further divided with respect to failures (actual failed components) and nonfailures (time change removals, removals to facilitate other maintenance, etc.).

Since the distribution of first removal times of new items included both removals for failure and nonfailure causes, an approach must be made to determine the percentage of failure cause removals which recognizes the diminishing population due to the nonfailure cause removals as well.

2.4 Determining Percentage of Failure From Multicensored Data

The fraction of components that have failed $F(t)$ through time interval t is expressed by the following equation:

$$F(t) = 1 - P_{(t)} \tag{51}$$

where $P_{(t)}$ = the probability of survival through time interval t

P_t values are formed by multiplying together a sequence of estimates of conditional probabilities P_i of survival through intervals 0 to 99 hours, 100 to 199 hours, etc. A typical factor p of this sort can be estimated several ways, where the number of items n at the beginning of the interval is known to be reduced by n_f failures and n_{nf} nonfailures within the interval but the order in which these occur is not known.

$$\overline{p} = \frac{n - n_f}{n} \tag{52}$$

could be used if all the failures were known to precede all the nonfailure removals.

$$\underline{p} = \frac{n - n_f - n_{nf}}{n - n_{nf}} \tag{53}$$

could be used if all the nonfailure removals preceded all failure removals. However, here it is evident that $\underline{p} \leq P_i \leq \overline{p}$. An equation for an intermediate value for p is provided in reference 31,

$$P_i = \frac{n_i - n_{f_i} - n_{nf_i}/2}{n_i - n_{nf_i}/2} \tag{54}$$

where 50 percent of the nonfailure-caused removals occur at the beginning of the interval and 50 percent at the end of the interval. Since, except for the initial interval, the 100-hour periodic inspections appear at the beginning and end of each 100-hour interval and since the periodic inspection time is the most probable time to remove nonfailed components, this equation appears to provide the best approach to the multicensored data analysis.

The n_i values are determined for each interval. For the first interval, 0 to 99 hours, n_1 equals the total number of units n_t in the analysis. For the second interval, 100 to 199 hours, n_2 equals n_t minus the number of failures n_{f_1} and the number of nonfailure-caused removals n_{nf_1} in the first interval. For the third interval, 200 to 299 hours, $n_3 = n_t$ minus the number of failures n_{f_i} and the number of nonfailure-caused removals n_{nf_i} through the first two intervals. This expressed as an equation is

$$n_r = n_t - \sum_{i=1}^{i=r-1} n_{f_i} + n_{nf_i} \tag{55}$$

where n_r = the number of assemblies at the beginning on interval r

The probability of survival is determined for each 100-hour interval using the data and the above equations.

The accumulative probability of survival P_r through time interval r is determined for each interval using the following equation:

$$P_r = \prod_{i=1}^{i=r} P_i \tag{56}$$

The accumulative fraction of components that have failed F_r through time interval r is determined using equation (51).

The resulting set of accumulative failure values is plotted on the Weibull graph paper, and a straight line is drawn through the points to represent the Weibull distribution. The characteristic life θ, the slope parameter β, and the mean of the projected distribution μ are determined as previously described.

2.5 Determining the Characteristics of an Exponential Distribution Which Has Correspondence With the Weibull

The slope parameter β in a Weibull distribution identifies the characteristic of the failure rate. When β equals one for the special case where the Weibull distribution is also the exponential distribution, the failure rate is a constant for different time values. Where β is less than one, the failure rate of the distribution decreases with increasing time; when β is greater than one, the failure rate increases as time increases. For most dynamic components which have an assigned operating period of time to removal for overhaul or retirement, the β values are slightly greater than one. This indicates that there is a slight wear characteristic which causes an increased frequency of removal as the components approach time change.

In general, the desirable time to be established for time change is a period just prior to where the wear rate would appear to accelerate (i.e., where secondary damage may become significant).

Since the exponential equations are used most frequently in reliability computations and since the β for the Weibull distributions of most dynamic components are close to one, it is desirable to determine an exponential distribution which has a correspondence with each Weibull distribution.

This is accomplished graphically by drawing a line with a β slope of one through the point where the Weibull distribution line intersects a time equal to the time change. The rationale for selecting this point is that both the Weibull and exponential distributions so drawn have the same percentage of assemblies which survive to time change. The characteristic life which is the mean of the exponential distribution is obtained by observing the time value where the exponential distribution line intersects 62.3 percent failures. This mean is the MTBF value which will be used to estimate the MTBR values described in the following subsection.

In the example presented in Section 4.0 of this appendix, the exponential distribution has a larger percentage of failed components at the end of each 100-hour interval than the Weibull distribution up to the point of time change. The effect of using the exponential distribution instead of the Weibull distribution for spare component requirement estimations is that although the same number of premature replacements are required, the exponential analysis would indicate that a larger number would be required earlier.

Note that beyond time change, both distributions are truncated and spares would be required to replace the remaining components removed at that time.

2.6 Estimating Mean-Time-Between-Removal Values Using the Exponential Mean (MTBF)

In Section 6 of the report, equation 27 was developed which estimates the MTBR of an exponential distribution truncated at time change T_c:

$$MTBR_e = MTBF \left(1 - e^{-\frac{T_c}{MTBF}} \right)$$

This equation shall be used to estimate the MTBR for the exponential distribution plotted on the Weibull graph paper.

2.7 Adjusting the Estimated MTBR for Repaired Items Recycled Into the Inventory

It was observed in Section 7 of the report that a fraction of the components removed for failure are repaired (not overhauled) locally and are later reinstalled to continue

operating until they either fail again or are removed for time change. Note that the repaired components are not set back to zero time as are overhauled components. Their accrued time on reinstallation is the same as the time accrued when they were removed for failure. The repaired components are in effect a set of short-life components which have the same MTBF as the nonrepaired components but which also have a new potential time-to-removal life span of time change T_c minus the accrued time at failure T_f. Failures and subsequent repairs can occur and reoccur. The MTBR of a distribution which includes both repaired and non-repaired components is lower than the MTBR of the distribution which contains only the nonrepaired assemblies. This analysis considers only two repair cycles. Computations of additional cycles have shown but little additional change in the total MTBR.

For this analysis, the K factor representing the fraction of failed components that are repaired, assigned to each type of component, is the largest value shown in Section 7 of the report for that component regardless of part number or aircraft model. This approach was taken since there is a large percentage of the components for which the action taken on the removed component is not identified.

The K values assigned are:

Tail rotor hub	.15	90-degree gearbox	.05
Tail rotor blade	.08	Hanger assembly	.04
42-degree gearbox	.07		

The equations developed to estimate the MTBR of a distribution with a population that includes the initial removals for failure and time change and a group of repaired failed assemblies which are subsequently removed for a second or subsequent failures or time change, were the result of a coordinated effort between Bell's Project Engineer for the program and the Government's Technical Representative for the program. Where the distribution contains one repair cycle (i.e., initial failures, repair, and second failures), the mean-time-between-removals has been identified as MTBR'. MTBR" similarly corresponds to a distribution containing, in addition to the assemblies in previous distribution, assemblies having a second repair cycle.

The MTBR' and MTBR" equations are based on two assumptions:

a. The mean-time-to-removal for the failed assemblies (MTR_f) is equal to the MTR of the repaired assemblies.

Since there are criteria which would preclude the repair of assemblies which fail near time change, the true MTBR' and MTBR" values would probably be higher than those obtained using the equations of this analysis.

b. The MTBF for the initial population and the groups of repaired components is constant.

The following shows the development of the equations.

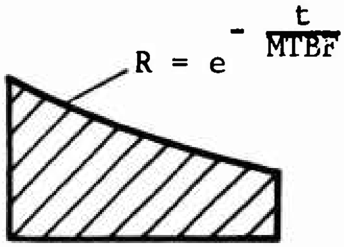
MTBR' is determined by summing the total time to removal for failure and time change for a population of n components having a known MTBF with the additional total time to removal for failure or time change of a smaller group of n' repaired components which have a potential life to time change T_C-MTR_{f_1} , and dividing the result by the sum of n and n'.

MTR_{f_1} is determined by subtracting from the product of $MTBR_e$ and n the product of T_C and the number of components n_{T_C} which are removed for time change, and dividing the result by the number of component removed for failure ($n-n_{T_C}$).

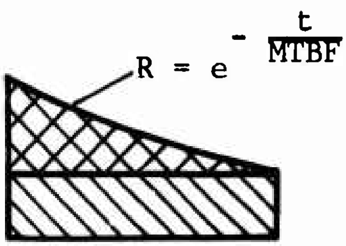
MTBR" is determined by summing the product of MTBR' and (n"+n') with the additional total time to removal for failure or time change achieved by a still smaller group of n" repaired components (a fraction of the n' group failures) which have a potential life to time change of T_C - MTR_{f_2}, and dividing the result by n + n' + n".

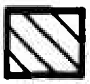
MTR_{f_2}, the mean-time-to-removal of the components that failed, were repaired, and which failed a second time, is determined from n' population in the same manner as MTR_{f_1} was determined from the n population.

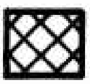
The following are the derivations and the resulting equations for MTR_{f_1} and MTBR':



Area  $= N \times MTBR_e = N\left[MTBF\left(1 - e^{-\frac{T_c}{MTBF}}\right)\right]$

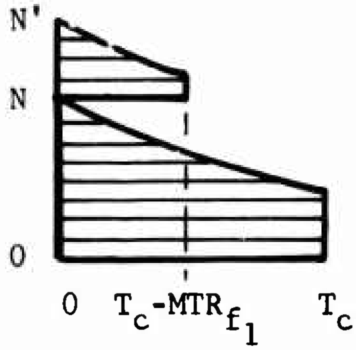


Area  $= n_{T_c} \times T_c = N\left(e^{-\frac{T_c}{MTBF}}\right) T_c$

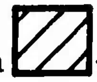
Area  $= MTR_{f_1}\left(N - n_{T_c}\right) =$ Area  $-$ Area 

$$MTR_{f_1} = \frac{N\left[MTBF\left(1 - e^{-\frac{T_c}{MTBF}}\right)\right] - N\left(e^{-\frac{T_c}{MTBF}}\right)T_c}{N - N\left(e^{-\frac{T_c}{MTBF}}\right)}$$

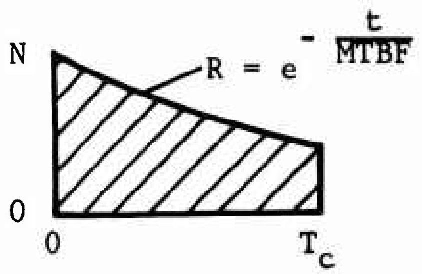
$$= MTBF - \frac{\left[e^{-\frac{T_c}{MTBF}}\right]T_c}{\left[1 - e^{-\frac{T_c}{MTBF}}\right]} \qquad (57)$$

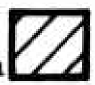


$$N' = N + \left(N - n_{T_c}\right) K$$

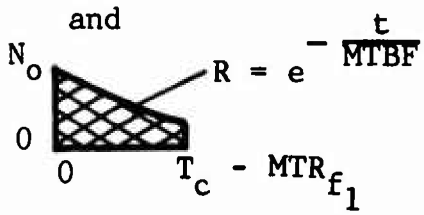
Area  = MTBR' x N' = Area  + Area 

where

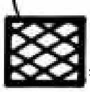


Area  $= N \times MTBR_e$

and



$$N_o = \left(N - n_{T_c}\right) K$$

Area  $= MTBR_{f/R_1} \times N_o$

$MTBR_{f/R_1}$ = Mean-Time-Between-Removal for components that failed, were repaired and were put back into the system.

$$\mathrm{MTBR}' = \frac{N \times \mathrm{MTBR}_R + \mathrm{MTBR}_{f/R_1} \times N_o}{N'}$$

$$= \left\{N \times \mathrm{MTBF}\left(1 - e^{-\frac{T_c}{\mathrm{MTBF}}}\right)\right.$$

$$\left. + \mathrm{MTBF}\left(1 - e^{-\frac{T_c - \mathrm{MTR}_{f_1}}{\mathrm{MTBF}}}\right)\left[N - N\left(e^{-\frac{T_c}{\mathrm{MTBF}}}\right)\right] K\right\} \Bigg/$$

$$\left\{N + \left[N - N\left(e^{-\frac{T_c}{\mathrm{MTBF}}}\right)\right] K\right\}$$

$$= \frac{\mathrm{MTBR}_e + \mathrm{MTBF}\left[1 - e^{-\frac{T_c - \mathrm{MTR}_{f_1}}{\mathrm{MTBF}}}\right]\left[1 - e^{-\frac{T_c}{\mathrm{MTBF}}}\right] K}{1 + \left[1 - e^{-\frac{T_c}{\mathrm{MTBF}}}\right] K} \qquad (58)$$

Following the same derivation procedure the equations for MTR_{f_2} and MTBR" results as follows:

$$\mathrm{MTR}_{f_2} = \mathrm{MTBF} - \frac{\left[e^{-\frac{T_c - \mathrm{MTR}_{f_1}}{\mathrm{MTBF}}}\right]\left(T_c - \mathrm{MTR}_{f_1}\right)}{\left[1 - e^{-\frac{T_c - \mathrm{MTR}_{f_1}}{\mathrm{MTBF}}}\right]} \qquad (59)$$

$$
MTBR'' = \left\{ MTBR_e + MTBF\left[1 - e^{-\frac{T_c - MTR_{f_1}}{MTBF}}\right]\left[1 - e^{-\frac{T_c}{MTBF}}\right]K + MTBF\left[1 - e^{-\frac{T_c - MTR_{f_1} - MTR_{f_2}}{MTBF}}\right]\left[1 - e^{-\frac{T_c}{MTBF}}\right]\left[1 - e^{-\frac{T_c - MTR_{f_1}}{MTBF}}\right]K^2 \right\} \Bigg/ \left\{ 1 + \left[1 - e^{-\frac{T_c}{MTBF}}\right]K + \left[1 - e^{-\frac{T_c}{MTBF}}\right]\left[1 - e^{-\frac{T_c - MTR_{f_1}}{MTBF}}\right]K^2 \right\} \qquad (60)
$$

3.0 THE RESULTS OF THE ANALYSIS

The analysis results consider both the Weibull distribution of failure-caused removals versus time and the Weibull distribution of all cause removals versus time.

3.1 The Weibull Distribution Characteristics

Table CXV presents the tail rotor system components' Weibull distribution characteristics, β, θ, mean and percentage of failures at time change (TBO), and the MTBF of the exponential distributions which have the same percentage surviving to time change as the Weibull distributions. The table shows that except for some of the tail rotor hubs and one of the hanger assemblies, the β slopes of the Weibull distribution of failure-caused removals are less than 1.20. This is comparatively close to an exponential distribution.

A comparison of the β slopes of the two sets of Weibull distributions indicates that while there is a slightly increasing failure rate for most of the distributions of failure-caused removals, the distribution for removals for all causes is very close to or slightly less than 1.0. This means that the distribution of nonfailure-caused premature (prior to time change) removals must have a fairly significant decreasing removal rate. This condition is most pronounced for the tail rotor hub assemblies. During the data period, special inspections were introduced on the hub assemblies that resulted in premature removals at scheduled times so that prescribed examination processes could be conducted. This may have introduced a distortion to the data that is not observable in the MIRF reports. It may well be that the earlier-calendar-date premature removals were primarily for failure cause, while the later date removals were for nonfailure, inspection purposes.

TABLE CXV. FAILURE AND REMOVAL DISTRIBUTION CHARACTERISTICS

Component (Time Change, TBO) Part Number	Model	Removals for Failure Causes					All Removal Causes			
		β	θ (hr)	Weibull Dist. Mean (hr)	% Failure at TBO	Exponential Dist. MTBF (hr) **	β	θ	Weibull Dist. Mean (hr)	Exponential Dist. Mean (hr) **
Tail Rotor Hubs (1100-hour Life)										
204-011-701-11	UH-1D	1.74	792	706	83.00	621	1.33	440	404	324
204-011-701-19	UH-1D	1.20	1206	1134	59.13	1229	.84	148	162	202
204-011-801-5	UH-1D	1.55	795	715	80.93	664	1.06	335	328	312
204-011-801-9	UH-1D	1.32	542	499	92.19	432	1.10	253	244	219
204-011-701-19	UH-1H	1.10	1696	1635	46.22	1773	.81	149	168	218
204-011-801-5	UH-1H	1.18	683	646	82.68	627	.95	272	278	291
204-011-801-9	UH-1H	1.18	654	619	84.15	597	1.02	324	322	318
All D/H Hubs	D/H	1.27	799	742	77.70	733	.89	217	230	260
209-010-701-3	AH-1G	1.14	630	601	84.88	582	.97	140	143	151
204-011-801-3	AH-1G	1.20	478	450	93.39	405	1.06	247	241	224
All G Hubs	AH-1G	1.22	512	479	92.23	431	.99	189	190	192
All the Hubs	D/H/G	1.24	740	690	80.84	672	.90	211	222	249
T/R Blades (1100-hour Life)										
204-011-702-15	UH-1D	1.03	1310	1295	56.62	1317	1.02	378	376	372
204-011-702-15	UH-1H	1.14	800	764	76.24	765	.96	335	340	349
All D/H Blades	D/H	1.12	866	832	72.90	842	.97	343	347	354
204-011-702-17	AH-1G	1.04	615	606	83.94	602	.94	222	229	246
All the Blades	D/H/G	1.08	815	791	74.91	796	.95	312	319	331
42° Gearbox (1500-hour TBO)										
204-040-003-23	UH-1D	1.11	1530	1470	62.40	1533	1.02	1096	1086	1088
204-040-003-37	UH-1D	.98	1666	1632	59.44	1662	.99	1011	1017	1016
204-040-003-37	UH-1H	1.10	1024	989	78.14	986	1.07	772	752	736
All D/H 42's	D/H	1.06	1234	1207	70.74	1220	1.04	873	860	855
204-040-003-37	AH-1G	1.05	895	877	82.12	871	.96	644	655	664
All the 42's	D/H/G	1.05	1170	1147	72.71	1155	1.02	831	824	822

TABLE CXV. (Continued)

Component (Time Change, TBO) Part Number	Model	Removals for Failure Causes: β	θ (hr)	Weibull Dist. Mean (hr)	% Failure at TBO	Exponential Dist. MTBF (hr) **	All Removal Causes: β	θ (hr)	Weibull Dist. Mean (hr)	Exponential Dist. Mean (hr) **
90° Gearbox (1100-hour TBO)										
204-040-012-7	UH-1D	1.10	1768	1705	44.70	1857	1.10	1168	1126	1175
204-040-012-13	UH-1D	.94	1655	1700	49.35	1617	.94	984	1015	991
204-040-012-13	UH-1H	1.14	1079	1031	64.02	1076	1.09	820	795	800
All D/H 90's	D/H	1.07	1243	1210	58.41	1254	1.03	882	870	876
204-040-012-13	AH-1G	1.12	960	921	68.80	944	1.06	688	673	670
All the 90's	D/H/G	1.08	1191	1157	60.06	1198	1.04	847	835	839
D/S Hanger Assy (None*)										
204-040-600-7	UH-1D	1.09	1112	1075	99.44	965	1.04	766	753	706
204-040-600-9	UH-1D	1.01	685	683	99.44	672	1.06	451	441	390
204-040-600-7	UH-1H	1.25	948	882	99.97	623	1.20	624	587	412
204-040-600-9	UH-1H	1.01	[illegible]	732	99.91	718	1.04	548	539	500
All D/H Hangers	D/H	1.02	822	815	99.82	791	1.04	[illegible]	570	533
204-040-600-9	AH-1G	1.00	675	676	99.94	678	.96	[illegible]	464	497
All the Hangers	D/H/G	1.02	806	801	99.83	782	1.03	565	559	533

* Time change of 5000 flight hours (approximate aircraft life) has been used for computation purposes.

** These MTBF values are the means of exponential distributions which have the same percentage surviving to TBO or time change as components' Weibull distributions.

3.2 Comparison of the MTBR Values Estimated by This Analysis Procedure and the MTBR Values Estimated in Section 6

Table CXVI presents the Weibull distribution mean values, the MTBF values of the exponential distributions that were created on the basis of the same percentage of components having failed at time change, and estimated MTBR values that were computed using the MTBF values and equation 27. The MTBF and $MTBR_e$ values that were presented in Section 6 for the same components are shown for comparison.

The relationship between the Weibull mean and the exponential MTBF generally depends on the percentage of failures at time change and the β slope. As shown in Figure 30, if the percentage of failures at time change is less than 62.3 and if the β is less than 1.0, then the mean of the Weibull distribution is always greater than the exponential MTBF. Also, if the percentage of failures at time change is less than 62.3 and if β is greater than 1.0, then the mean is always less than the exponential MTBF. If, however, the percentage of failures is greater than 62.3 and β is either less than or greater than 1.0, the mean can be either greater than or less than the exponential MTBF or approximately equal to it.

Except for the hanger assembly, nearly all of the MTBF/$MTBR_e$ values computed for the components using the procedures of this appendix are less than the comparable MTBF/$MTBR_e$ values obtained in Section 6.

Table CXVII compares the means of Weibull distributions and exponential distributions which consider removals for all causes. The relationship between these means is also as shown in Figure 30, described above. The MTBR estimated using the exponential mean and equation 27 is compared with the MTBR/MTR values for removals for all causes shown in Section 6. The differences between these values vary from zero to 47 percent. The greatest difference appears for the rotor hub, hanger assembly, and one of the 42-degree gearboxes. The maximum difference is about 9 percent for the blades and 5 percent for the 90-degree gearbox.

3.3 MTBR Adjustments Due to Off-Aircraft Repair

Table CXVIII shows how the MTBR reduces as a fraction of the failed assemblies are repaired and are used as replacement units. Since the fraction that is so repaired is small (4 to 15 percent), the percentage of change in MTBR from a single repair is also small--less than 3 percent. The additional percentage of change in MTBR from the distribution with single repairs to one which also includes a second repair cycle is extremely small--less than 0.5 percent.

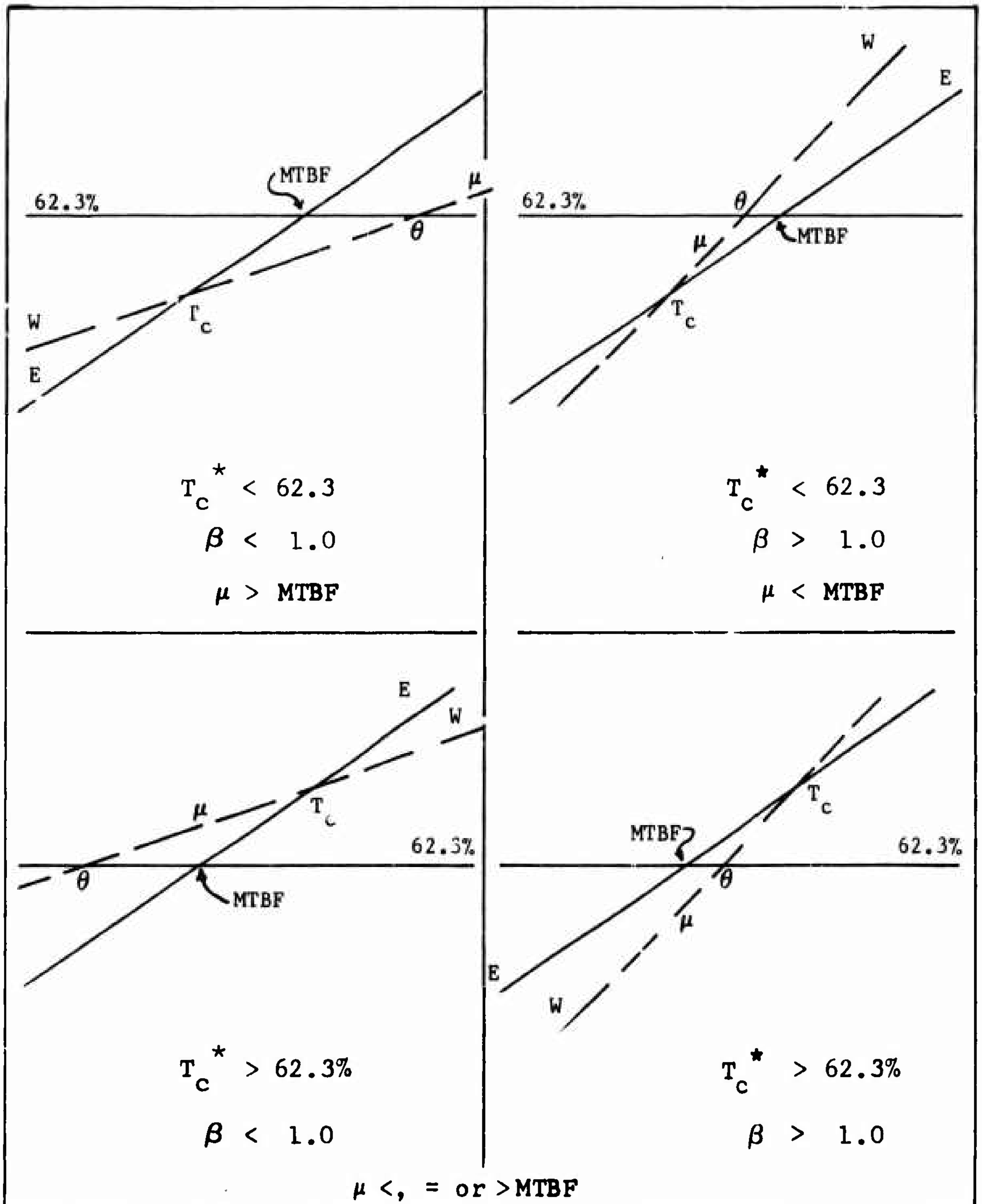
TABLE CXVI. WEIBULL DISTRIBUTION MEAN VALUES AND EXPONENTIAL DISTRIBUTION MTBF AND $MTBR_e$ VALUES BASED ON FAILURE-CAUSED REMOVALS

Component (Time Change, TBO) Part Number	Model	Weibull Dist. Mean (hr)	Exponential Dist. MTBF (hr)	MTBF From Section 6 (hr)	$MTBR_e$	
					From Expo. Dist. MTBF	From Sect. 6 MTBF
Tail Rotor Hubs (1100-hour Life)						
204-011-701-11	UH-1D	706	621	1012	515	671
204-011-701-19	UH-1D	1134	1229	1558	727	789
204-011-801-5	UH-1D	715	664	1040	537	679
204-011-801-9	UH-1D	499	432	612	398	511
204-011-701-19	UH-1H	1635	1773	1850	820	829
204-011-801-5	UH-1H	646	627	852	519	618
204-011-801-9	UH-1H	619	597	746	502	575
All D/H Hubs	D/H	742	733	1004	570	668
209-010-701-3	AH-1G	601	582	632	494	521
204-011-801-3	AH-1G	450	405	535	378	567
All G Hubs	AH-1G	479	431	569	397	437
All the Hubs	D/H/G	690	672	898	541	634
T/R Blades (1100-hour Life)						
204-011-702-15	UH-1D	1295	1317	1335	746	749
204-011-702-15	UH-1H	764	765	871	583	625
All D/H Blades	D/H	832	842	924	614	643
204-011-702-17	AH-1G	606	602	638	505	524
All the Blades	D/H/G	791	796	857	596	620
42^{o} Gearbox (1500-hour TBO)						
204-040-003-23	UH-1D	1470	1533	1637	957	982
204-040-003-37	UH-1D	1682	1662	1575	988	967
204-040-003-37	UH-1H	989	986	1076	771	809
All D/H 42's	D/H	1207	1220	1271	863	881
204-040-003-37	AH-1G	877	871	924	715	742
All the 42's	D/H/G	1147	1155	1206	840	858

TABLE CXVI. (Continued)

Component (Time Change, TBO) Part Number	Model	Weibull Dist. Mean (hr)	Exponential Dist. MTBF (hr)	MTBF From Section 6 (hr)	$MTBR_e$	
					From Expo. Dist. MTBF	From Sect. 6 MTBF
90^{o} Gearbox (1100-hour TBO)						
204-040-012-7	UH-1D	1705	1857	1791	830	822
204-040-012-13	UH-1D	1700	1617	1624	798	799
204-040-012-13	UH-1H	1031	1076	1146	689	707
All D/H 90's	D/H	1210	1254	1311	732	744
204-040-012-13	AH-1G	921	944	982	650	662
All the 90's	D/H/G	1157	1198	1253	720	732
D/S Hanger Assy (None *)						
204-040-600-7	UH-1D	1075	965	645	960	645
204-040-600-9	UH-1D	683	672	665	672	665
204-040-600-7	UH-1H	882	623	889	623	886
204-040-600-9	UH-1H	732	718	709	717	708
All D/H Hangers	D/H	815	791	693	790	692
204-040-600-9	AH-1G	676	678	652	678	652
All the Hangers	D/H/G	801	782	689	781	689

* Time change of 5000 flight hours (approximate aircraft life) has been used for computation purposes.



* Percentage of failure at T_c is equal for both distributions.

Figure 30. Weibull Mean μ and the Exponential MTBF Relationships.

TABLE CXVII. WEIBULL DISTRIBUTION MEAN VALUES AND EXPONENTIAL DISTRIBUTION MEAN AND ESTIMATED MTBR VALUES BASED ON REMOVALS FOR ALL CAUSES

Component (Time Change, TBO) Part Number	Model	Weibull Dist. Mean (hr)	Exponential Dist. Mean (hr)	(1) Estimated MTBR (hr)	(2) MTBR From Section 6 (hr)	% Difference Between MTBR Values $\frac{(2)-(1)}{(1)} \times 100$
Tail Rotor Hubs (1100-hour Life)						
204-011-701-11	UH-1D	404	324	313	389	+24.3
204-011-701-19	UH-1D	162	202	202	151	-25.2
204-011-801-5	UH-1D	328	312	303	318	+ 5.0
204-011-801-9	UH-1D	244	219	218	238	+ 9.2
204-011-701-19	UH-1H	168	218	217	157	-27.6
204-011-801-5	UH-1H	278	291	284	264	- 7.0
204-011-801-9	UH-1H	322	318	308	308	0.0
All D/H Hubs	D/H	230	260	256	215	-16.0
209-010-701-3	AH-1G	143	151	151	126	-16.6
204-011-801-3	AH-1G	241	224	222	235	+ 5.9
All G Hubs	AH-1G	190	192	191	176	- 7.8
All the Hubs	D/H/G	222	249	246	208	-15.4
T/R Blades (1100-hour Life)						
204-011-702-15	UH-1D	376	372	352	354	+ 0.6
204-011-702-15	UH-1H	340	349	334	319	- 4.5
All D/H Blades	D/H	347	354	338	326	- 3.6
204-011-702-17	AH-1G	229	246	243	321	- 9.1
All the Blades	D/H/G	319	331	319	301	- 5.6
42° Gearbox (1500-hour TBO)						
204-040-003-23	UH-1D	1086	1088	814	619	-24.0
204-040-003-37	UH-1D	1017	1016	784	682	-13.0
204-040-003-37	UH-1H	752	736	640	687	+ 7.3
All D/H 42's	D/H	860	855	707	679	- 4.0
204-040-003-37	AH-1G	655	664	595	585	- 1.7
All the 42's	D/H/G	824	822	689	675	- 2.0

TABLE CXVII. (Continued)

Component (Time Change, TBO) Part Number	Model	Weibull Dist. Mean (hr)	Exponential Dist. Mean (hr)	(1) Estimated MTBR (hr)	(2) MTBR From Section 6 (hr)	% Difference Between MTBR Values $\frac{(2)-(1)}{(1)} \times 100$
90° Gearbox (1100-hour TBO)						
204-040-012-7	UH-1D	1126	1175	714	729	+ 2.1
204-040-012-13	UH-1D	1015	991	665	697	+ 4.8
204-040-012-13	UH-1H	795	800	598	614	+ 2.7
All D/H 90's	D/H	870	875	626	647	+ 3.3
204-040-012-13	AH-1G	673	670	540	550	+ 1.9
All the 90's	D/H/G	835	839	613	632	+ 3.1
D/S Hanger Assy (None *)						
204-040-600-7	UH-1D	753	706	706	373	-47.2
204-040-600-9	UH-1D	441	390	390	430	+10.3
204-040-600-7	UH-1H	587	412	412	560	+35.9
204-040-600-9	UH-1H	539	500	500	515	+ 3.0
All D/H Hangers	D/H	570	533	533	465	-12.8
204-040-600-9	AH-1G	464	497	497	435	-12.5
All the Hangers	D/H/G	559	533	533	462	-13.3

* Time change of 5000 flight hours (approximate aircraft life) has been used for computation purposes.

TABLE CXVIII. COMPONENT MTBR VALUES ADJUSTED FOR OFF-AIRCRAFT REPAIR

Component (K) (Time Change, TBO) Part Number	Model	$MTBR_e$ (hr)	MTBR' (hr)	% Change $MTBR_e$ to MTBR'	MTBR" (hr)	% Change MTBR' to MTBR"
Tail Rotor Hubs (.15) (1100-hour Life)						
204-011-701-11	UH-1D	515	505	2.02	503	.44
204-011-701-19	UH-1D	727	708	2.62	706	.28
204-011-801-5	UH-1D	537	526	2.14	524	.44
204-011-801-9	UH-1D	398	393	1.23	392	.38
204-011-701-19	UH-1H	820	800	2.42	798	.18
204-011-801-5	UH-1H	519	508	2.04	506	.44
204-011-801-9	UH-1H	502	493	1.94	490	.44
All D/H Hubs	D/H	570	556	2.30	554	.43
209-010-701-3	AH-1G	494	485	1.89	483	.44
204-011-801-3	AH-1G	378	374	1.08	373	.36
All G Hubs	AH-1G	397	393	2.21	391	.38
All the Hubs	D/H/G	541	530	2.16	527	.44
T/R Blades (.08) (1100-hour Life)						
204-011-702-15	UH-1D	746	735	1.44	734	.08
204-011-702-15	UH-1H	583	576	1.32	575	.12
All D/H Blades	D/H	614	606	1.38	605	.12
204-011-702-17	AH-1G	505	500	1.34	499	.14
All the Blades	D/H/G	596	588	1.28	587	.12
42° Gearbox (.07) (1500 hour TBO)						
204-040-003-23	UH-1D	957	945	1.28	944	.07
204-040-003-37	UH-1D	988	975	1.28	975	.07
204-040-003-37	UH-1H	771	762	1.13	761	.10
All D/H 42's	D/H	863	853	1.24	852	.09
204-040-003-37	AH-1G	715	708	1.03	707	.10
All the 42's	D/H/G	840	830	1.22	829	.09

TABLE CXVIII. (Continued)

Component (K) (Time Change, TBO) Part Number	Model	$MTBR_e$ (hr)	MTBR' (hr)	% Change $MTBR_e$ to MTBR'	MTBR" (hr)	% Change MTBR' to MTBR"
90^{o} Gearbox (.05) (1100-hour TBO)						
204-040-012-7	UH-1D	830	823	.83	823	.02
204-030-012-13	UH-1D	798	791	.87	791	.02
204-040-012-13	UH-1H	689	683	.92	682	.04
All D/H 90's	D/H	732	726	.92	725	.03
204-040-012-13	AH-1G	650	644	.91	643	.04
All the 90's	D/H/G	720	713	.92	713	.04
D/S Hanger Assy (.04) (None*)						
204-040-600-7	UH-1D	960	959	.04	959	.00
204-040-600-9	UH-1D	672	672	.00	672	.00
204-040-600-7	UH-1H	623	623	.00	623	.00
204-040-600-9	UH-1H	717	717	.01	717	.00
All D/H Hangers	D/H	790	789	.01	789	.00
204-040-600-9	AH-1G	678	678	.00	678	.00
All the Hangers	D/H/G	781	781	.01	781	.00

* Time change of 5000 flight hours (approximate aircraft life) has been used for computation purposes.

For all assemblies, the percentage of change shown was computed before the MTBR' and MTBR" values were rounded to whole numbers. As a result, there is a percentage of change noted in Table CXVIII for some components where MTBR' values appear to be equal to the MTBR" values.

4.0 TRACING THE ANALYSIS OF THE UH-1H, 90-DEGREE GEARBOX, PART NUMBER 204-040-012-13 AS AN EXAMPLE

Table CXIX, extracted from the UH-1H MIRF report (Reference 4), shows how the distributions of failure, nonfailure new-item first-time removals are presented in these data for the UH-1H 90-degree gearbox, Part Number 204-040-012-13. The following paragraphs describe the analysis performed on these data.

The total number of assemblies removed is 2817. The probability of surviving the first 100-hour interval is computed using equation 54:

$$P_1 = \frac{n_1 - n_{f_1} - n_{nf_1}/2}{n_1 - n_{nf_1}/2} = \frac{2817-206-99/2}{2817-99/2} = .925565$$

The percentage of failures through the first 100-hour interval is determined using equation 51:

$$F(t_1) = (1-P_{t_1})100 = (1 - .925565)100 = 7.4435$$

The number of assemblies remaining at the start of the second 100-hour interval is determined using equation 55:

$$n_2 = n_T - \sum_{i=1}^{i=r-1} n_{f_i} + n_{nf_i} = 2817-206-99 = 2512$$

Again using equation 54, the probability of surviving the second 100-hour interval is

$$P_2 = \frac{2512-144-74/2}{2512-74/2} = .941818$$

TABLE CXIX. UH-1H RAMMIT MIRF 90-DEGREE GEARBOX DATA*

FIRST REMOVAL - NEW ITEM

FUNCTIONAL GROUP 04 ROTOR, TRANSMISSION SYS/CLUTCHES ILLUS 198

GEARBOX ASSY, 90 DEG FSN 16159182677 PN 20404001213 MFR CODE 97499 USED ON MODELS BCDH

FLIGHT HOUR-INTERVALS	0000 0099	0100 0199	0200 0299	0300 0399	0400 0499	0500 0599	0600 0699	0700 0799	0800 0899	0900 0999	1000 1099	1100 1199	1200 1299	1300 1399	1400 1499	1500 1599	1600 1699	ABOVE 1700
FAILURES — SUMMARY BY FLIGHT HOUR INTERVAL																		
TOTAL IN INTERVAL	206	144	150	194	180	151	144	124	112	101	59	8	1	1				2
CUMULATIVE TOTAL	206	350	500	694	874	1025	1169	1293	1405	1506	1565	1573	1574	1575	1575	1575	1575	1577
PERCENT IN INTERVAL	13.1	9.1	9.5	12.3	11.4	9.6	9.1	7.9	7.1	6.4	3.7	.5	.1	.1	.0	.0	.0	.1
CUMULATIVE PERCENT	13.1	22.2	31.7	44.0	55.4	65.0	74.1	82.0	89.1	95.5	99.2	99.7	99.8	99.9	99.9	99.9	99.9	100.0
NONFAILURES — SUMMARY BY FLIGHT-HOUR INTERVAL																		
TOTAL IN INTERVAL	99	74	74	41	56	54	31	54	39	46	328	333	1		2	7		1
CUMULATIVE TOTAL	99	173	247	288	344	398	429	483	522	568	896	1229	1230	1230	1232	1239	1239	1240
PERCENT IN INTERVAL	8.0	6.0	6.0	3.3	4.5	4.4	2.5	4.4	3.1	3.7	26.5	26.9	.1	.0	.2	.6	.0	.1
CUMULATIVE PERCENT	8.0	14.0	19.9	23.2	27.7	32.1	34.6	39.0	42.1	45.8	72.3	99.1	99.2	99.2	99.4	99.9	99.9	100.0
NEW ITEMS (INCLUDES FAILURES AND NONFAILURES) — SUMMARY BY FLIGHT-HOUR INTERVAL																		
TOTAL IN INTERVAL	305	218	224	235	236	205	175	178	151	147	387	341	2	1	2	7		3
CUMULATIVE TOTAL	305	523	747	982	1218	1423	1598	1776	1927	2074	2461	2802	2804	2805	2807	2814	2814	2817
PERCENT IN INTERVAL	10.8	7.7	8.0	8.3	8.4	7.3	6.2	6.3	5.4	5.2	13.7	12.1	.1	.0	.1	.2	.0	.1
CUMULATIVE PERCENT	10.8	18.6	26.5	34.9	43.2	50.5	56.7	63.0	68.4	73.6	87.4	99.5	99.5	99.6	99.6	99.9	99.9	100.0

* From pages 216 and 217 of Reference 4.

The probability of surviving through the second 100-hour interval is determined using equation 56:

$$P_{t_2} = \prod_{i=1}^{i=r} P_i = P_1 \times P_2 = .925565 \times .941818 = .871714$$

The percentage of failures through the second 100-hour interval is determined using equation 51:

$$F(t_2) = (1-P_{t_2})100 = (1-.871714)100 = 12.8286$$

This process continues until the percentage of failures through each of the first ten 100-hour intervals are determined. Table CXX presents the values determined by using each of the equations in this procedure.

TABLE CXX. DETERMINING PERCENTAGE OF FAILURE VALUES

100-Hour Interval	n_i	n_{f_i}	n_{nf_i}	P_i	P_{t_i}	$F(t_i)$ Percent
1	2817	206	99	.925565	.925565	7.44
2	2512	144	74	.941818	.871714	12.83
3	2294	150	74	.933540	.813780	18.62
4	2070	194	41	.905343	.736750	26.32
5	1835	180	56	.900387	.663360	33.66
6	1599	151	54	.903944	.599640	40.04
7	1394	144	31	.895539	.537001	46.30
8	1219	124	54	.895973	.481138	51.89
9	1041	112	39	.890357	.428385	57.16
10	890	101	46	.883506	.378481	62.15

The $F(t_i)$ values are plotted on the Weibull graph paper as shown by the dots on Figure 31. The distribution of the total removals for all causes is plotted as inverted triangles using the values shown for the cumulative percentage at the bottom of Table CXIX. A solid line has been drawn through the dots and a dash-dot-dot line has been drawn through the inverted triangles. These two lines represent the two Weibull distributions.

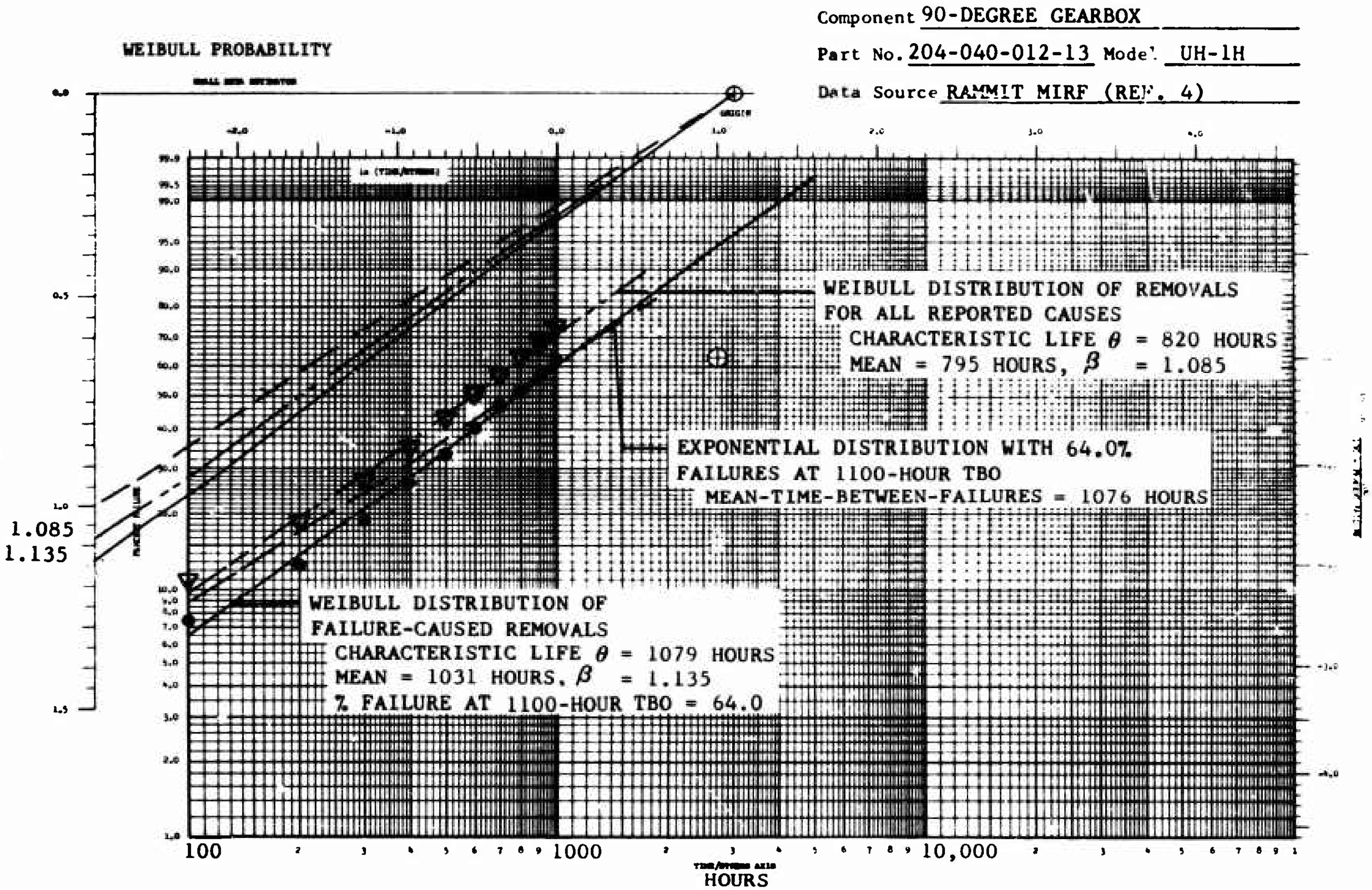


Figure 31. Plot of Distributions on Weibull Graph Paper.

The distribution of failure-caused removals has the following characteristics:

1.14 = β, the slope

1079 hours = θ, the characteristic life

64.0 = Percentage of failures at 1100-hour time change

The distribution of the components removed for all causes has the following characteristics:

1.08 = β, the slope

820 hours = θ, the characteristic life

74.70 = Percentage of removals prior to the 1100-hour time change

The mean values for the two distributions are determined by first, on Figure 32, determining the percentage of failures at the mean for the two β values and then by determining the time value where these values intersect the

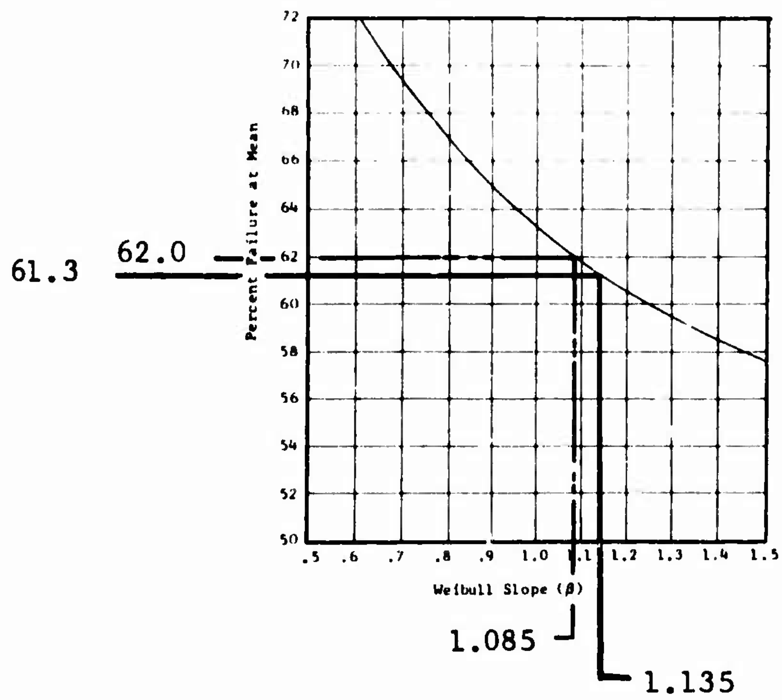


Figure 32. Plot To Determine Percentage of Failure of the Weibull Mean From β.

respective distribution lines on the Weibull graph paper. The mean values so determined are:

1031 hours = the mean of the distribution of failure-caused removals

795 hours = the mean of the distribution of the components removed for all causes

The characteristics of an exponential distribution having the same percentage of failures at time change as the Weibull distribution are determined by drawing a line with a β slope of 1.0 through the intersection of the Weibull distribution line and 1100 hours. This is shown as a dashed line on Figure 31. The characteristic life θ (62.3% failures) of this distribution is 1076 hours. θ is also the MTBF of this exponential distribution.

Using as input to equations 27, 57, 58, 59, and 60 an MTBF of 1076 hours, a time change T_c of 1100 hours, and a K repair factor of 0.05, the following values are computed:

$$MTBR = 689 \text{ hours}$$

$$MTR_{f_1} = 485 \text{ hours}$$

$$MTR_{f_2} = 278 \text{ hours}$$

$$MTBR' = 683 \text{ hours}$$

$$MTBR'' = 682 \text{ hours}$$

5.0 CONCLUSIONS AND RECOMMENDATIONS

This approach provides a means of rapidly predicting MTBF values from histograms of failure-caused component removals and component removals for nonfailure causes. The data can be plotted on Weibull graph paper as described, or it can be used as input to computer programs which in turn will provide answers that are more accurate. During this exercise, both techniques were employed.

One of the most significant advantages of this technique is the ability of estimating the MTBF and MTBR values for a finite number of components initially installed on a fleet of aircraft based on the failure- and nonfailure-caused removals which occur during the initial 300 to 400 flight

hours. The accuracy of the estimate will increase as the higher time removals are included. Particularly where the distribution is Weibull with a β greater than 1.0, this approach will provide a much more accurate basis for estimating spare component requirements or life-cycle costs than can be obtained by a simple computation of the observed MTBF (total time accrued/number of failures) at the same time period.

The accuracy of this approach depends either on having a large population of removed assemblies or knowing the total number of components installed of which the components removed are a subset. Most of the MIRF data fall into the first classification since the installed component history is unavailable. Where MIRF data contain only a small number of component removals, the analysis using the Weibull approach would be inaccurate.

A simulation program is recommended where spare requirements or support costs are desired for specific periods of demand, changing demand rates, various sizes of aircraft groups, etc.

END